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THE GOLD DEPOSITS OF THE PHILIPPINE ISLANDS.[1]

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INTRODUCTION.

The Philippine Islands form a part of the series of curved island chains, festooning the eastern coast of the continent of Asia from the Andaman to the Aleutian Islands, and lie between 4° and 21° N. latitude. The number of the islands in the Philippine group is variously given as from one to two thousand, as it is difficult to make a distinction between true islands and rocks. The largest island, Luzon, has an area of about 122,000 sq. km., the second, Mindanao, about 94,000, and the total area of the Philippines exceeds 300,000 sq. km.

The great majority of the natives belong to branches of the Malay race; Mohammedans (Moros) in the south along the southern coast of Mindanao and in the Sulu Archipelago; Christian tribes of varying degrees of civilization in the coastal regions of the central and northern islands; and savage tribes in the interior highlands.

The islands were first known to Europe through Magellan's discovery in 1524, and were a Spanish colony until they came into American possession in 1898, as a result of the war with Spain. The natives had been in rebellion against the Spanish

[1] Published by permission of the Director, Bureau of Science, Manila.

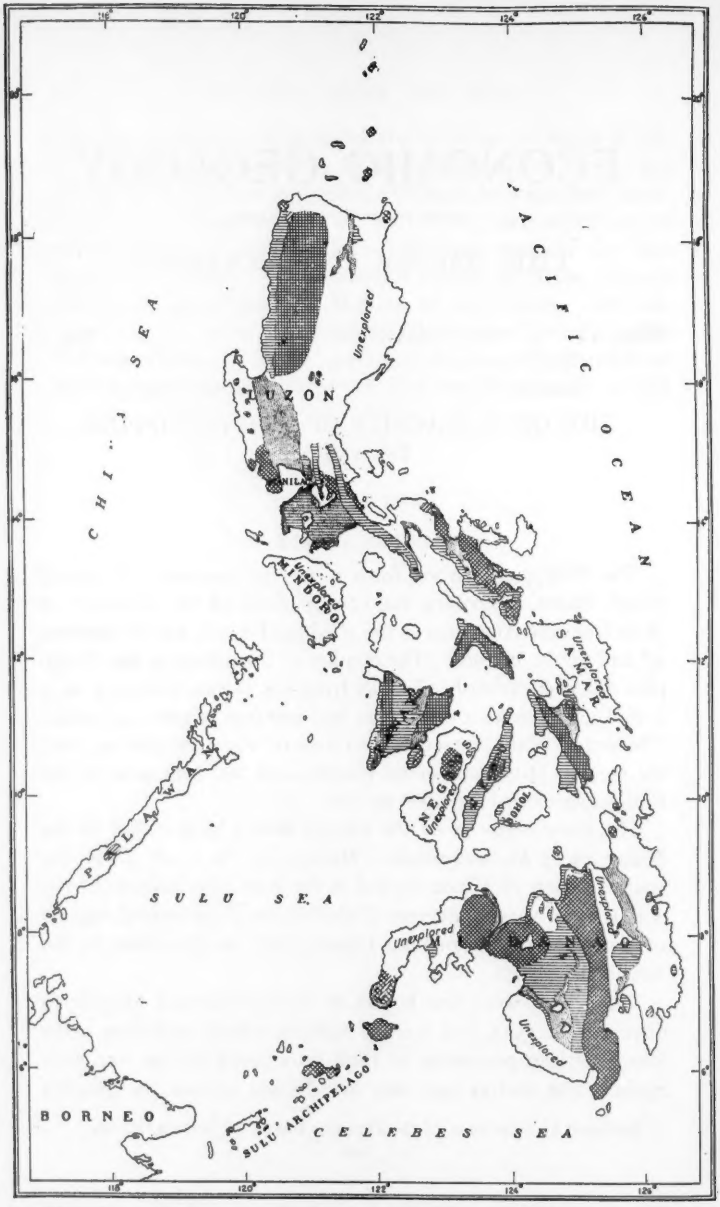


FIG. 11. Geological Map of the Philippines.

government since 1896, and an insurrection broke out against the Americans in 1899, which was not suppressed until 1902, with sporadic outbreaks in different islands until 1906.

GEOLOGY.

As first pointed out by Becker,[1] the southern islands are arranged according to two main curved systems intersecting at angles of about 60 degrees. To the inner series belong the islands of Palawan and Culjon, and parallel to this line, the group formed by the Sulu Archipelago, the Zamboanga peninsula of Mindanao, the islands of Negros, Cebu and Panay, and the western arm of Masbate. The northern part of Borneo continues this trend to the southwest. The curve of the outer series has a greater radius, and a center of curvature to the south of the first. It includes the two transverse ranges of Mindanao, the islands of Leyte and Samar, the eastern arm of Masbate, the southern part of Luzon and probably the island of Mindoro. To the southward this series is continued in the Sangir group and the island of Celebes in the Dutch East Indies. The islands do not follow one another in regular lines but are slightly offset, so that the longer diameters of successive islands are roughly *en êchelon* in their arrangement. In the larger features of their distribution they follow the two dominant trends of crustal movement, in all probability the inner series being of earlier date.

On the large island of Luzon the relation of structure to topography is less clear. Southeast of Manila are the active and extinct volcanoes of the Taal Group. Northwestward from Manila Bay, the Zambales Range runs parallel to the coast as far as the Gulf of Lingayen, and in the eastern part of the island an unexplored cordillera runs northward until it joins a transverse knot of mountains, the Caraballo Sur, in about latitude 16° N. Between these two ranges is the broad Pampanga valley covered with alluvial deposits, which are underlaid by late Tertiary waterlaid tuffs. Two mountain ranges branch out to the northward

[1] Becker, G. F., "Report on the Geology of the Philippine Islands," U. S. G. S. 21st Annual Report, Pt. III., pp. 487–614.

from the Caraballo Sur. The eastern is the unexplored Sierra Madre range, extending northward to the volcanic islands between Luzon and Formosa, and known to contain a core of older crystallines flanked, on the west at least, by Tertiary sediments. Between the Sierra Madre and the western range, the Cordillera Central, is the broad synclinal Cagayan valley containing Tertiary limestones. To the westward of the Cordillera Central is a small coast range.

While the central ranges of a majority of the islands contain metamorphosed sediments, no fossiliferous formations of earlier date than the Oligocene have been found and it is not at all certain that pre-Tertiary sediments exist.[1] In the Tertiary series marked unconformities exist in the Miocene, and between the Miocene and Pliocene.

The distribution of volcanoes follows the anticlinal lines, though it is not possible, as has been attempted by earlier writers, to group them into comprehensive volcanic belts. Series of volcanoes along anticlines are well shown in the Sulu archipelago, the islands of Negros, southern Luzon and the line of volcanoes of the northern islands.

The Philippines appear to owe their present form to the great upheaval at the close of the Miocene. This was accompanied by intense volcanic action and in two, at least, of the three important mining districts, vein formation followed the period of volcanism. Periods of later uplift are shown in the comparatively undisturbed Pliocene and Pleistocene coral limestones whose terraces surround the shores of the majority of the islands. Late Pleistocene depression, or rather an increase in the volume of the ocean water,[2] is abundantly shown both in the distribution of life in different islands, showing former land connections,[3] and in the submarine topography. This change of level appears to

[1] Smith, W. D., "Philippine Geology," *Min. Res. of the P. I.*, Manila, 1910, pp. 54–56. Contains table of Philippine stratigraphy.

[2] Daly, R. A., "Pleistocene Glaciation and the Coral Reef Problem," *Amer. Jour. Sci.*, Vol. 30, 1910, pp. 297–308.

[3] Worcester, Dean C., and Bourns, F. S., "Contributions to Philippine Ornithology," U. S. Nat. Mus. Pub., No. 1134, Vol. 20.

have amounted to between sixty and a hundred and fifty meters, and is of economic importance, first in the production of so many good harbors by the drowning of river valleys and, secondly, in allowing a probably deeper zone of oxidation in the veins than would have been the case had the land remained at its present level or been recently uplifted.

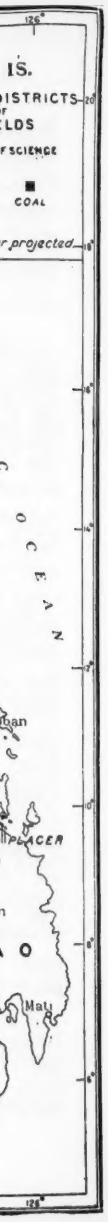
THE MINING DISTRICTS.

Although gold is widely distributed throughout the older crystalline and volcanic rocks of the central ranges of most of the islands, it is only in three regions, the Baguio, Aroroy and Paracale districts that development is at all advanced. The reasons for this lie partly in the difficulty of exploration in a tropical and savage country, and partly in purely local causes. Political difficulties have also delayed the introduction of capital. During the last five years, however, the gold production has increased from practically nothing in 1905 to almost $300,000 in 1909, but the more important mines have not as yet attempted any large production, and have wisely confined their efforts to development work.[1] Such success as has attended American mining here is due to the fact that the volunteer regiments forming the first army of occupation were composed of men of the western states, many of whom were experienced miners and prospectors. To those who remained in the islands after receiving their discharges, the credit for the present development of our mineral wealth is due. In both Baguio and Aroroy the first American prospectors were on the ground in advance of the troops. In the former district these pioneers reached the field before the outbreak of the insurrection in February, 1899, and were obliged to obtain passes from the rebels on their return to the American lines. In the Aroroy district the pioneer prospector was twice made prisoner by the insurgents before the island of Masbate

[1] The report of the director of the U. S. Mint for 1910 shows an apparent falling off in Philippine gold production. This is due, however, to the fact that a large proportion of the gold now mined in the islands is sold in Japan. The production for 1910 is a marked increase over that for 1909 though exact figures are not yet available.

MAP OF
PHILIPPINE IS.
SHOWING
PRINCIPAL MINERAL DISTRICTS
AND DISTRIBUTION OF
KNOWN COAL FIELDS
PREPARED BY
DIVISION OF MINES, BUREAU OF SCIENCE
LEGEND
GOLD. COPPER IRON. COAL
R R completed
R R partly completed or projected
BATANES IS.
BABUYANES
Laoag
Aparri
Vigan
Tuguegarao
MANCAYAN
San Fernando
Baguio
Casiguran
Dagupan
Tarlac
PENARANDA
ANGAT
Polillo
Cavite
Manila
PARACALE
Lagonoy
Bacanga
Nva. Caceres
Tabaco
CATANDUANES I.
Boaco
Legaspi
MINDORO
Romblon
BULALACAO
MASBATE
SAMAR
Catbalogan
Culion
Capiz
Tacloban
PANAY
Cuyo
Iloilo
Ormoc
LEYTE
San Jose
Bucolod
NEGROS
CEBU
Cebu
PALAWAN
Puerto Princesa
BOHOL
Surigao
Dimaguete
PLACER
Dapitan
Cagayan
Iligan
Misamis
MINDANAO
Cotabato
Davao
Cagayan Sulu
Zamboanga
Sandakan
Jolo
Siasi
BORNEO
Bongao
SULU ARCHIPELAGO
CHINA SEA
PACIFIC OCEAN
SULU SEA

FIG. 12.



was fully occupied by the American troops, and the first miners more than once had to defend themselves against attacks from bands of ladrones.

The Baguio District.—Of the three mining districts, the most important in point of production, is that of Baguio in the subprovince of Benguet in central Luzon. Here shallow work has been carried on for an unknown time by the Igorot savages, but in Spanish times the difficulties of transportation and the unsettled state of the country prevented development. The Igorot workings consist of small open cuts and tunnels, often so narrow as to be impossible of access to the white man, the rock being broken by fire and crushed in stone mortars.

These naked savages are good metallurgists and in the copper district of Lepanto to the north of Benguet have been smelting copper since before the Spanish conquest. In the Baguio region to-day the Igorot is very clever at alloying the gold he expects to sell to the Americans or Chinese, with just the right amount of copper to allow it to pass unsuspected.

Since the American occupation a good road has been built to the district from Dagupan, the terminus of the Manila Railroad, and in the near future the railroad will be continued to the district itself. At present three stamp mills and two cyanide plants are in operation. The production for 1907 was $78,000, 1908 $140,000, and 1909 $122,000. The falling off for 1909 was due to heavy floods, which partially wrecked all three mills, stopping work for three months.

The mining district lies a short distance south and east of the town of Baguio, the summer capital of the Philippines, on a tableland of about 1,500 meters elevation between the Cordillera Central and the coast range, and comprises an area of over 100 square kilometers. This tableland is deeply dissected by the canyons of the Bued, Sili and Antamok rivers. The latter flows through heart of the mining district and supplies the power for the mills.

Although this district is the most important of the three in point of production no detailed study of the geology has yet been made.

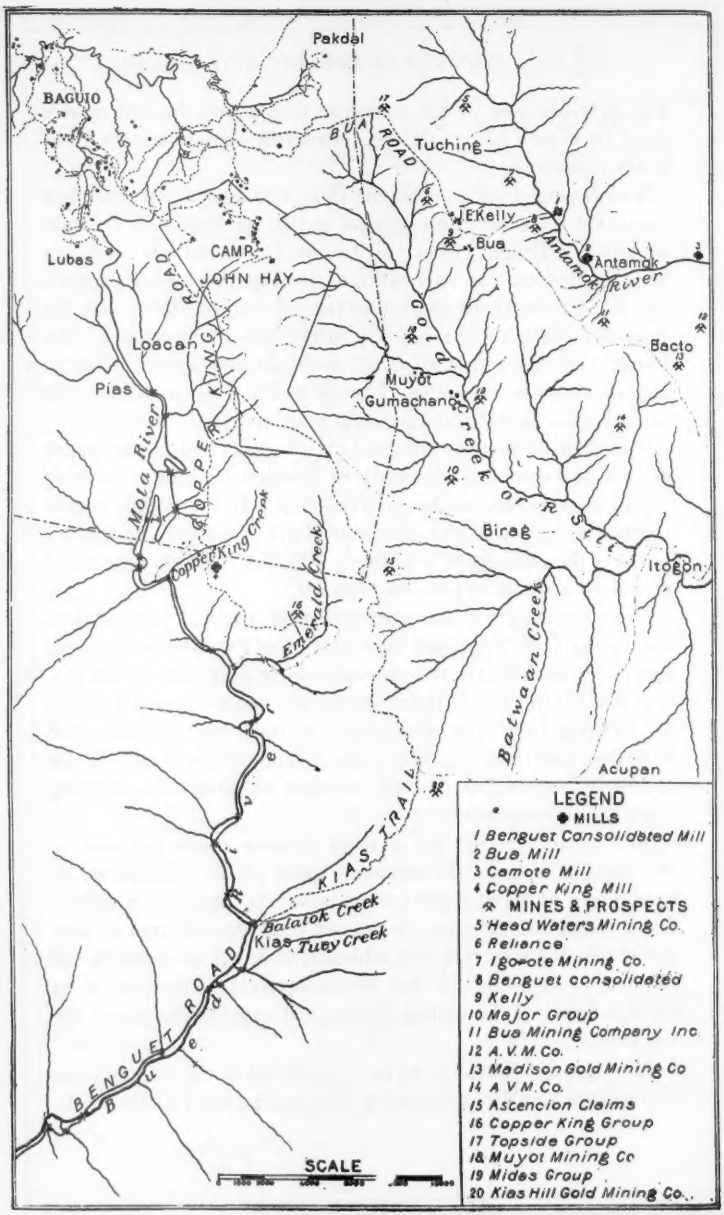


FIG. 13. Map of the Baguio District.

From Eveland's reconnaissance[1] it appears that there is a basal mass of diorite of similar composition to that forming at least a very large part of the Cordillera Central, associated with which is quartz diorite, probably intrusive. This basal mass in early Tertiary times formed an island upon whose shores were laid down a conformable series of early Miocene sediments. Following the great crustal movements of the Miocene extensive volcanic action took place, giving a series of augite-andesites with subordinate hornblende andesites and pyroclastic rocks. The period of vein formation followed the igneous activity.

According to Eddingfield,[2] the majority of the veins are fissure veins in andesite, although contact deposits between andesite and limestone and between andesite and diorite have been reported. The veins often occur in groups of four and about 250 have been uncovered. They vary from one-half to six meters in width, and attain a maximum of 15 meters. The strike is almost invariably east, normal to the trend of the mountain ranges, and the dip generally steep to the south.

The gangue varies greatly, consisting in different veins of white quartz, banded crystalline quartz, calcite, calcite and rhodocrosite, brown manganese oxide and quartz, silicified and mineralized andesitic dikes and brecciated quartz. As a rule the gold content is about 50 per cent. free milling, though, in the few veins where telluride ores occur, no free gold is found. The gold occurs both free and included in pyrite, and in rare instances as a telluride, and generally largely alloyed with silver, the silver content being occasionally as high as 33 per cent. Manganese oxide and rhodocrosite are often very prominent, but no copper, lead or zinc minerals are present. The ore is not of high grade, 15 grams to the metric ton being common, though richer patches are sometimes met with.

The Baguio district has many natural advantages for cheap mining. The deeply incised river valleys allow of most of the

[1] Eveland, A. J., "Notes on the Geology and Geography of the Baguio Mineral District," *Phil. Jour. Sci.*, Sec. A, Vol. 2, pp. 203–233, 1907.

[2] Eddingfield, F. D., "The Baguio Mineral District," *Min. Res. of the P. I.* Bureau of Science, Manila, 1910, pp. 14–17.

mining being carried on by adits, as well as offering excellent mill-sites, and good water power is available. The labor situation is not at present pressing. Cheap Igorot labor, though generally useless underground, is available for surface work, such as road building and cutting timber. Underground and about the mills, the steadier Christian natives from the coast must be employed. Japanese are often used for timbermen and carpenters. The most serious disadvantages are the comparative scarcity of timber, the great distance from the coast, making transportation difficult and expensive, and the danger from landslides and floods.

The two most important companies operating in this field are the Bua and the Consolidated.[1] The former is working two narrow veins, one of quartz from one half to one meter in width, and the other of rhodocrosite from one to two meters wide. The ore is mined by overhead stoping, the stopes being filled with waste broken in mining. The mill consists of two three stamp batteries with copper plates. The tailings are cyanided in six sand leaching tanks. The Consolidated is working a wider vein and has so far confined its efforts to development work. The mill consists of six stamps, the tailings from the plates being classified and leached by a sand and slime leaching plant, and the leached slimes filtered in a Ridgeway vacuum filter. Other mines of importance are the Camote, operating a three-stamp mill, the Headwaters, now installing a ten-stamp mill and cyanide plant, and the Kelley group, the latter being of especial interest as here three intersecting veins, with strikes of N. 60° W., N. 60° E. and N. 34° W., at variance with the usual east-west strike, carry tellurides, but no free gold.

Development work has progressed further in the Baguio district than elsewhere in the islands and a large increase in production may be expected in the near future.

The Aroroy District.—The Aroroy mining region lies near the northeastern point of the island of Masbate. As it has been my good fortune to make a preliminary study of the geology,

[1] Eddingfield, *loc. cit.*, p. 16.

MAP OF THE AROROY DISTRICT.

I shall describe this district in greater detail.[1] Masbate owes its unique two-pronged shape to the junction of the two anticlinical trends of the southern islands. The two ranges are in part composed of older sediments, largely slates, intruded throughout large areas by diorites and more basic plutonic rocks, and associated with a large amount of later volcanics, chiefly augite-andesite and pyroclastics, with more basic rocks. Along the southern shores, and inland on the flanks of the mountain range, scattered outcrops of a dark blue limestone are to be found, of lower Miocene or Oligocene age. In the southeast part of the island is a sedimentary series of Miocene age, containing coal, resting upon schistose quartz diorite. These sediments are bent into sharp folds whose axes follow the prevailing northwesterly trend. On the northwest corner of Masbate a similar formation, consisting of shales, limestones and conglomerate, but as far as now known, without coal, extends southwestward along the western shore of the island. The dip here is quite gentle and generally to the west.

The mining district is situated in a group of hills to the east of Port Barrera, a deep bay extending southward for a distance of about 13 kilometers. Mount Vil-lon, the highest mountain in the district has an elevation of about 400 meters, and differs from the other hills in having a northeasterly trend. The majority of the veins outcrop in the three hills, Mt. Aroroy (255 meters), Mt. Bagadilla (350 meters) and Mt. Kalakbao (220 meters) which show a pronounced northwesterly trend, due to the resistance to erosion offered by the quartz veins.

Neither the Guinobatan River nor its northern branch, the Bangon Creek, follow the strike of the quartz veins, but cut obliquely across them, suggesting superposition of an older drainage system. The Lanang River presents a very peculiar course, apparently the result of successive stream captures, for instead of flowing down the broad valley to the north of the Lanang range, its earlier course, it twice cuts through the range in deep gorges.

[1] "The Aroroy Mining District," *Min. Res. of the P. I.*, Bureau of Science, Manila, 1910, pp. 18–25.

The oldest rocks in the area are a series of slates occupying an irregular belt of lowland running northward from the western flank of Mt. Vil-lon to the eastern slope of Mt. Aroroy, with scattered outcrops in the northern part of the district. No fossils have been found, but judging from its position, its extreme contortion and considerable metamorphism, it is my belief that these sediments may be provisionally classed as pre-Tertiary, the earliest fossiliferous formation found here being the little disturbed sedimentary series across the bay.

In the northern part of the area these older sediments are intruded by quartz-diorite, which forms the small hills north of Mt. Aroroy.

As in the Baguio region, volcanic rocks and their pyroclastic derivatives cover by far the larger portion of the district, but here show greater petrographic variety. Augite-andesite is here, as elsewhere in the Philippines, the commonest igneous rock. With the appearance of olivine the augite-andesite passes into a basalt, while on the other hand the presence of hornblende in place of the augite gives the hornblende-andesite, often difficult to distinguish from the augite-andesites in the decomposed rocks so frequently met with, owing to the alteration of the femic minerals. At one place enough quartz is found under the microscope to bring the rock into the rank of dacite. The greater part of the more basic rocks are basalts differing from one another and from the augite-andesite in the relative proportions of olivine, the varieties of the feldspars present and the relative preponderance of the femic minerals. From their scattered distribution it is probable that they occur in dikes cutting the andesites and earlier rocks. A leucite-tephrite is found in a single outcrop, probably as a dike cutting the agglomerate. This is all the more likely as a dike of a similar though more decomposed rock cuts the sediments on the Gold Bug claim.

Pyroclastic rocks cover the greater part of the central portion of the area. Most of these rocks are agglomerates, containing large angular blocks often exceeding half a meter in width, and always derived from augite-andesite. With the agglomerate are

small beds of andesitic tuff and volcanic ash, but these are comparatively unimportant. Where contacts are found, the strike is northwest and the dip rather gentle to the southwest.

Waterlaid sediments derived from the augite-andesite are found in two localities, in Panique Creek, and on the Gold Bug claim, at the mouth of the gorge of the Guinobatan, in both cases suggesting temporary lacustrine conditions.

On a small southerly spur of Mt. Bagadilla, just at the eastern end of the gorge of the Guinobatan River, at an elevation of about 150 meters, is a small outcrop of a dark blue limestone of lower Miocene or Oligocene age, similar to that found in places along the main range of the island. Thick jungle surrounds the outcrop, and the field relations are consequently uncertain.

South of the Lanang River is a rather coarse conglomerate composed largely of basalt pebbles, evidently the basal member of the sedimentary series. Above this in the hills between the abandoned meander and the mass of andesite forming the lower gorge of the Lanang is conglomerate and sandstone, dipping about 20° to the southwest.

On the northern shore of the westward embayment of Port Barrera, a fine grained gray shale containing shells of Lower Miocene age outcrop on the beach. This shale is considered by Dr. W. D. Smith to be identical with that found above the coal measures in Cebu and Batan, and, in the hope of finding similar coal seams, was here prospected by drilling to a depth of fifty meters, but only shale encountered. This evidence, together with that furnished by the topography of the country, makes it clear that Port Barrera was originally a river valley eroded in the soft shales and drowned in a recent depression. Hence, it seems probable that the low land lying south of the head of this bay represents the lower portion of the shale, and it is here that the coal measures should be looked for. Above the shale is an unconformity marked by 8 or 10 meters of conglomerate which contains pebbles of augite-andesite and vein quartz, evidently derived from the Aroroy district. Above the conglomerate are several beds of limestone belonging to the Upper Miocene or Pliocene.

Large mangrove swamps are found along the southern shore of Port Barrera, estimated by Whitford[1] as about ten square kilometers in area.

Probably in late Eocene or Miocene times came the uplift which bowed up the southeasterly anticline which to-day forms the backbone of the Island of Masbate. Accompanying this was a period of vulcanism, which was followed by the principal period of vein formation. The universal northwesterly trend of the main series of veins is evidence that the fissuring was resultant upon the continued bending up of the anticline. Even later than the period of vein formation, there may have been further igneous action, as shown in the dike on the Gold Bug claim. In all probability the leucite tephrite is of the same late date. A little later, or perhaps contemporaneous with the intrusion of these later dikes there was fissuring and faulting in an east and west direction in the region of the present Guinobatan River, giving the minor series of east and west veins which fault the older and more important series.

After the period of vein formation came submergence and the laying down of the marine sediments, now found in the extreme southern part of the area and in a later phase on the western shores of Port Barrera.

The veins of the Aroroy district were undoubtedly worked in early times, even before the Spanish conquest. In the account by Gemelli Careri[2] of his trip around the world, an interesting description of the district is given. His ship put in at harbor on the island of Masbate, evidently Port Barrera, and he describes the mines as follows:

"They say Masbate is thirty leagues in compass, eight in breadth and proportionably long. Its ports are commodious for any ship to water. In it live about 250 Indian families which pay tribute in wax, salt and civet. But those that dwell in the mountains and come from other parts are more numerous. Here are such rich gold mines, 22 carats fine, that

[1] Whitford, H. N., "Report on Forest Conditions in the Mining Region of Aroroy, Masbate, P. I.," *Min. Res. of the P. I.*, Manila, 1910, pp. 72–78.

[2] "A Voyage Around the World," by John Francis Gemelli Careri, 1695–1698. Translated from the Italian. Published in a collection of voyages by Awnsham and Churchill, London, 1704.

the mate of the Galleon St. Joseph, aboard which I went over to New Spain, going ashore in one of them in a very short time dug out an ounce and a quarter of pure gold. They do not at present work these mines for want of industry in the Spaniards, who have commission every year from New Spain to lay out some hundred thousands of pieces of eight, with an allowance to them of ten per cent., take no care to look for gold in the mines. As for the Indians, if they have but a dish of rice, they never mind that precious metal, and if they gather any in the rivers it is when they are pressed for tribute and then they gather as much as serves to pay it."

The various members of the Spanish Inspeccion de Minas, who, during the latter half of the last century, wrote on the mineral resources of the Philippines, make no mention of Aroroy.

Old workings are found everywhere throughout the district, generally in the form of deep narrow open cuts, now partly caved in, whose walls show rounded faces as if worked by means of fire. Stone mortars and pestles are often found, showing the primitive nature of the ore treatment. There are also a few workings of later date, which consist of irregular gophering along rich streaks, sometimes opening out into small stopes and again narrowing down to inclined passages barely large enough to admit a man's body. The only mining of which the natives have any tradition was that an arrastra was worked about a hundred years ago, the ore being obtained from the old workings on Boston hill. The ore here is a hard quartz, and was broken by building fires against the face. Modern mining began with the American occupation. Unfortunately, between 1905 and 1907, there was a boom and three stamp-mills and two dredges were set up before any development work had been done. The district is now recovering from the collapse which followed, and honest development work is the rule.

The veins are confined to the igneous rocks, and, though small stringers of quartz and calcite are very common in the older slates, it is not to be expected that in rocks of this character large fissures should be developed as in the more resistant igneous and pyroclastic rocks; and it is reasonable to suppose that, should the underground workings on the three hills ever reach the level of

the slates, the veins will be found to split up into similar small stringers. As in Baguio, the veins are, as a rule, wide and regular. From two to six meters is a common width, with a maximum of 16 meters. Transverse faulting is rare, but motion parallel to the walls is the rule, particularly on the footwall. All the important veins follow a northwesterly direction and show very steep dips, those to the north of Guinobatan River to the northeast from 70° to vertical, while those on the southern side dip to the southwest from 50° to 80°. A few veins do not follow the dominant northwesterly strike, but have a nearly east-and-west course. These fault the main vein system, and are probably of no great commercial importance.

So far practically all the work has been done in the oxidized zone, and it is only in a few places that the unaltered form of the ore can be seen. This is typically a very hard dark blue quartz carrying irregular amounts of pyrite, the dark color being due to finely divided particles of manganese oxide. Small veins of more crystalline quartz cut across the fine grained dark quartz which makes up the body of the ore. Near the walls, especially the footwall, faint banding may sometimes be observed. In many veins calcite is a prominent gangue mineral in the sulphide zone. It is generally massive and dark blue or gray in color, similar to the quartz. Rhodochrosite has never been found in connection with these manganese bearing calcite ores, though in similar ores in Baguio this mineral is present. The calcite, where found, is generally associated with quartz in more or less parallel bands in the same vein, and when a piece of what appears to be massive calcite is dissolved in hydrochloric acid, it is always found to leave an intricate network of fine quartz ribbons.

The oxidized zone shows a marked change of appearance. Lines of weakness parallel to the walls have acted as channels for the surface water with the result that concentration of the different minerals in parallel bands has been accomplished, especially near the footwall, where the motion has been greatest. The calcite has been largely dissolved out and carried away, and the quartz has become bleached through the loss of its manga-

nese content, while the manganese oxide is deposited in bands, and less commonly, patches, sometimes of sooty wad, but more commonly broken quartz covered with manganese oxide. Similarly the pyrite has been oxidized and deposited in reddish bands of iron oxide. The quartz in the narrower bands is white, sometimes stained with iron oxide, and the larger bands show unoxidized cores of blue pyritized quartz. In the central parts of the veins, where the movements have not been so intense and the banding consequently not so pronounced, "honeycomb" quartz is formed by the loss of the calcite and manganese.

In different parts of the district all stages of alteration can be seen from the first bleaching of the blue quartz along small fissures to the final stage of oxidation where bands of massive quartz a meter or more in thickness have been completely bleached. In the oxidized zone the country rock is much altered near the veins, especially on the footwall side, this alteration often extending for several meters from the walls of the vein. The typical alteration product is a brown clay-like rock generally showing traces of its original porphyritic or fragmental structure, and much stained by manganese. This decomposed rock, whether of igneous or pyroclastic origin, has the local name of "porphyry." It is characteristically cut by a great number of small quartz and more rarely calcite stringers, which often carry values.

The comparatively great depth of the zone of oxidation found here, the Colorado workings being still in oxidized ore at a depth of over 100 meters below the summit of Mt. Bagadilla, is consequent upon the recent geologic history. The evidence furnished by the drowned valley of Port Barrera, and to a less degree by the Lanang River, show that the land in recent geologic times stood at a level probably over 50 meters above its present elevation. It remained at this level long enough for a broad valley to be eroded and consequently long enough for the oxidizing surface waters to reach a greater depth than would have been possible under conditions existing today.

In the oxidized zones of different veins differences in value

are noted between the veins carrying noticeable amounts of manganese and those in which iron oxide forms the metallic portion of the gangue. As far as a limited observation extends, all veins which on their outcrops show rich ore are those in which manganese oxide is not prominent. Evidence from development work, though very meager, seems to show that the values in these veins do not increase downward as is the case with the manganese-bearing veins, and in some at least decrease greatly a few meters from the surface. The manganese-bearing veins, on the other hand, which at their outcrop may be nearly barren, carry values increasing progressively downward. This increasing value in moderate depth is shown in many cases, but most clearly by samples taken in the 30-meter raise to surface from the upper level of the Nancy mine of the Eastern Mining Co. In this case there was an increase downward from the outcrop from less than one gram to over six grams per ton.

It is interesting to note how closely the conditions here agree with the hypothesis advanced by W. H. Emmons[1] relative to secondary enrichment, in the oxidized zone, of gold veins carrying manganese oxide. The Aroroy district is favorably situated for such enrichment, as the more important veins are only three or four kilometers from the sea coast and in a region of comparatively heavy rainfall, the average annual precipitation being about 1,400 millimeters. Consequently a high percentage of chlorine is to be expected in the surface waters. On the other hand, the increase in air circulation in the veins as compared with the country rock, is evidence that the broken and loose nature of the ore in the larger veins may allow mechanical transportation of the fine gold by downward flowing surface waters. In the lower level of the Colorado, an adit run on the vein, the air was found to be much better than in much shorter cross-cuts in the country rock. In the lower level of the Nancy a cross-cut was carried in from the side of the hill, and cut the vein at a

[1] Emmons, W. H., "The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold Deposits in the United States," *Bull. Am. Inst. Min. Eng.*, October, 1910, pp. 767–838.

depth of 90 meters below surface. Before the vein was reached there was great difficulty with the air, but as soon as the banded alternate broken and massive quartz was cut there was found to be a sufficient supply.

It had been considered that the segregations of the different minerals into bands must affect their values, and it was taken for granted that the more massive bands of quartz were barren, but careful sampling did not bear this out. As a rule, it may be said that the best values occur in rather irregular paystreaks, with a tendency to follow the footwall.

In the sulphide zone the prospects are not so favorable. The hard blue quartz will, of course, be more expensive to mine and mill than the broken material of the oxidized zone, and whatever has been added to the values by concentration or enrichment will be lacking. However, the depth to which the oxidized ore has been shown to extend seems to insure the future of the district.

The gold is only about 25 per cent. free milling, apparently due to the manganese oxide and though alloyed up to 10 or 20 per cent. by weight with silver, contains practically no copper and the ore is well suited to cyanide treatment. The veins outcrop on the hills, allowing the greater part of the oxidized ore to be removed by adits, and this, with the wide veins of shattered ore, makes mining cheap. The district is abundantly supplied with excellent timber, which at present is all obtained from the mining claims themselves. There is no good water power available, but the immense mangrove swamps which border the bay will furnish cheap firewood, and Philippine coal is obtainable at reasonable figures. The position of the district also gives it a great advantage. The mines are situated from three to seven kilometers inland from an excellent harbor, only a day's steaming from Manila, and consequently supplies are cheaper here than at other mining camps. At present the labor problem is also less pressing, and there has, up to now, been little difficulty in securing plenty of laborers at slightly lower wages than are paid elsewhere. It is estimated that in the more favorable situated mines, ore assaying over $3.50 a ton can be handled at a profit.

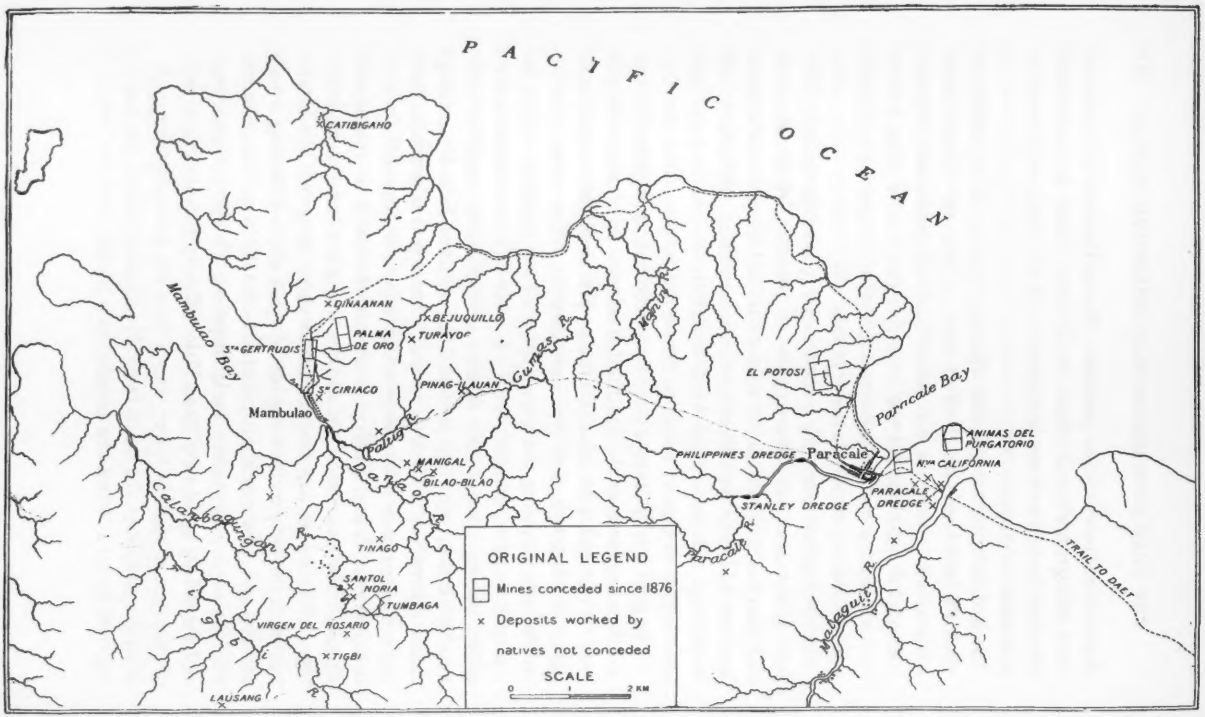


Fig. 14. Map of the Paracale District.

Two dredges formerly at work on the supposed placer grounds of the district have been unsuccessful, but this has been due in great measure to faults of management in one case and a combination of misfortunes in the other.

The Paracale District.—The third important district is that of Paracale[1] in the northern part of Ambos Camarines on the east coast of Luzon. During the Spanish times and before the Spanish conquest, until the insurrection of 1896, a large amount of gold was taken from the richest of the oxidized ores and the richest placers. One of the first military expeditions of the Spaniards after establishing themselves in Manila, was that of Juan Salcedo to take possession of these mines. Becker[2] quotes from a delightfully naïve report by one of the early Spanish writers. Hernando Riquel writing in 1574, says, "Trials have been made and the mineral presents itself so plentifully that I do not write about it, lest they suspect me of exaggeration, but it is sufficient to say, that I swear, as a Christian, that there is more gold in this island than there is iron in Biscay." Gemelli Carreri[3] states apparently on good authority, that the production in 1697 amounted to $200,000.

The natives in this district are fairly skilled miners and the women especially are very clever with the wooden batea. The accompanying photograph shows a model of a small dredge of native construction used on the rivers. The dredge is anchored by the spud in the center, and the pole, on the end of which is a hemp cloth bag, let down and a small amount of gravel brought to surface. This is then panned in the batea, or *faberik,* as it is locally called. At very low tide the Paracale River is often crowded with dugout canoes or *bancas* containing native women. The women work in pairs, one staying in the *banca* and the other standing up to her neck in water. The one in the water dives

[1] Ickis, H. M., "Camarines Gold Field," *Far Eastern Review,* Manila, Vol. 4, pp. 50–57, 1907. Ferguson, H. G., "Metallic Mineral Resources," *Mineral Res. of the P. I.,* Manila, 1909. Smith, W. D., "The Paracale-Mambulao District," *Min. Res. of the P. I.,* Manila, 1910.

[2] U. S. G. S., 21st Ann. Rept., Part 3, 1901, p. 579.

[3] Quoted by Becker, *loc. cit.,* p. 579.

FIG. 14. Map of the Paracale District.

down and fills the *faberik* with sand, which the other pans down to the black sand, which is washed out into a cocoanut shell. Later the black sand is carefully spread out on a dark cloth and the colors picked out with needles. The native women are so good at panning that one is always employed for this work in the crews of the testing outfits.

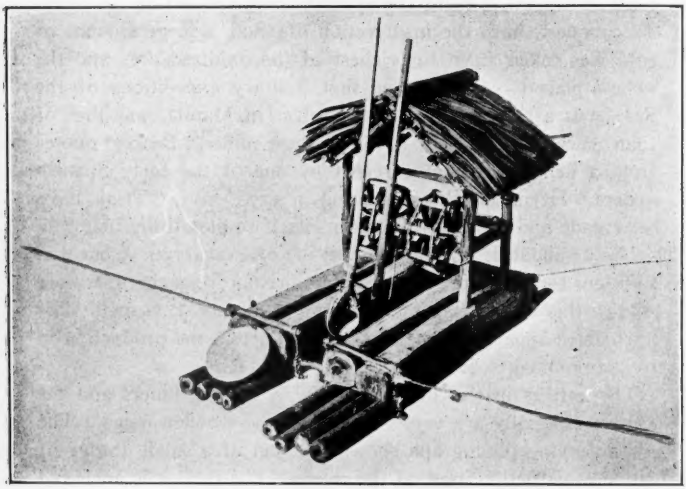


FIG. 15. Model of Native Dredge, used on the Paracale River.

Mining operations were carried on in a very crude manner until 1892, when work on a larger scale began. A small dredge, a ten-stamp mill and a small Huntington mill were installed between 1892 and 1896. Of these, the only survivor of the insurrection was the Huntington, which was repaired and used for a short time at one of the mines. The war and insurrection and the confusion in regard to titles, which followed, delayed operations for several years, but, in 1907, a small New Zealand dredge began work, and there are now three dredges and one twenty-stamp mill in the district, with prospects of more in the near future.

This district shows entirely different types of ores, though, unfortunately, no detailed study has yet been made. As far as is known, the region consists of a complex of pyroxenites and diorites, overlaid by sandstones and slates, all much metamorphosed and intruded by a mass of granite, the granite itself being gneissic and the whole complicated by andesitic and basaltic flows and dikes of various ages. It is in the vicinity of the granite intrusion that the principal veins are found, though it seems that none of the viens so far uncovered, are contact deposits, but cut both the granites and the older rocks.

Topographically the region is mature and the hills have gentle slopes, consequently the water level is comparatively near the surface; and the zone of oxidation a shallow one. The different ores show great mineralogical variety. While quartz is the usual gangue, calcite is not uncommon, and galena, zinc blende, pyrite, chalcopyrite and other copper sulphides, gold tellurides and free gold form the concentrates.

Two mines have now been developed to some extent. At one the ore consists of small calcite stringers containing different sulphides, together with tellurides and free gold, and often extremely rich, assays above $500 a ton being reported. These stringers occur in a zone of about ten meters width in a dark slate. The second mine has three parallel veins, which occur near the contact between the gneissic granite and the diorite schist, but cut both rocks. The ore is not of as high a grade as that of the former, but the veins are wide, there being reported to be large ore reserves assaying above $10 per ton. The gangue is quartz, containing copper sulphides and some free gold, which give a large proportion of concentrates, about one to seven. Although only the gold deposits of the district have so far been developed, other minerals are known to exist. Native copper has been found in small streams flowing north into the Malaguit River and in a clay, apparently a much decomposed andesite, in the vicinity. Apparently extensive deposits of hematite and magnetite are also known to exist south of the Malaguit River and near Mambulao Bay.

The two rivers, the Paracale and the Malaguit, which empty into the sea near the town of Paracale, are the sites of the principal placers. Both flow through wide valleys which contain large areas of available dredging ground. The principal values are obtained at a depth of from 10 to 14 meters in a layer of very rich quartz gravel averaging less than one half meter in thickness. This streak is so rich that, notwithstanding large losses due to its poor construction, the dredge first in operation obtained nearly two grams of gold per cubic meter of total ground dredged, excluding the values contained in the larger fragments of gold-bearing quartz saved for future crushing. It was not uncommon to see the tailings pile crowded with native women at work with their *faberiks*.

It is probable that the extremely rich ground now being worked is near points where the river cuts veins, the outcrops of which have not yet been discovered. The quartz pebbles brought up by the dredge are generally angular or subangular, and the gold caught in the riffles is usually sharp, and sometimes crystalline. The placer gold is from 95 to 98 per cent. pure. The granite bedrock beneath this deposit is much decomposed, and easily cut by the dredge buckets, making it possible to secure a large proportion of this rich gravel. There is a surface deposit of vegetable matter from two to five meters in thickness, which makes dredging difficult. Below this is a sticky gray clay, which contains some values. This clay balls excessively, and carries away gold from the tables. Again the black sand has proved a difficult problem and the proportion of fine material is larger than is usually met with.

Other Districts.—The three districts just described are the only places in the Philippines where mining is at all advanced. In other parts, preliminary prospecting has shown the existence of promising lode and placer deposits, and, when sufficient capital is available, no doubt new districts will be developed.

According to reports by Goodman[1] and Eddingfield[2] there is

[1] Goodman, M., "Gold Placers of Neuva Ecija," *Far Eastern Review*, Manila, Vol. 4, pp. 88–89, 1907.

[2] Eddingfield, F. T., "Neuva Ecija," *Min. Res. of the P. I.*, Manila, 1910, pp. 26–28.

a large area of placer ground, approximately 1,500 sq. km. in extent, along the eastern tributaries of the Pampanga River in the southern part of Nueva Ecija near the town of Peñaranda. The region is a rather flat plain watered by small wet weather streams. The gold-bearing sand is found in two layers, the upper reaching from one to two meters below surface, and underlaid by a "false bottom" of clay or sandstone of varying thickness, which overlies another similar bed of pay gravel, the total depth to bedrock varying from 8 to 12 meters. The upper sand has long been washed by the natives, and sluicing operations on a larger scale were carried on from 1890 to 1896 and again since 1905.

The gold occurs in extremely thin flakes, commonly under 3 mm. in diameter, though flakes up to 2 cm. diameter have been found. With the gold is a small amount of platinum, stated to amount to about one third of one per cent. of the gold content. Iridium has also been noted. Although values exceeding 15 cents per cubic meter were obtained in testing, dredging would be subject to several disadvantages, as the sand contains a large proportion of sticky clay, and, in parts of the area considerable amounts of black sand, besides which the flaky nature of the gold gives the fines a tendency to float. The gold is also said to be rusty and not readily amalgamable. The shortage of water during the dry season, the danger of heavy floods during the rains, and the passive hostility of the natives, are also drawbacks.

The portion of the cordillera from which this gold is derived, has never been explored, being inhabited by hostile savages, nor have the rivers draining eastward; but in the highlands of Bulakan and Rizal, in the southward continuation of the same range, both lode and placer deposits have been found, though the unsettled nature of the country has delayed exploration.

Concerning other regions there is little to say as yet. Prospects are being developed throughout the whole length of the Cordillera Central of Luzon, and this range will probably furnish other districts besides that of Baguio. At present prospecting is being carried on at the southern end of this range in the

province of Pangasinan and in the extreme north in Ilocos Norte. Many of the copper veins of the Mancayan-Suyok district north of Baguio also show considerable values in gold. Lately what is considered a continuation of the Paracale district has been found in the mountains to the southward, and promising placer ground southwest of Paracale at the head of Ragay Gulf is being tested. On the island of Catanduanes off the east coast of southern Luzon, lode and placer deposits are being developed. In the Visayan islands, besides the Masbate district already described, the northern part of the almost unexplored island of Mindoro contains placer grounds, and placers are likewise known to exist on the islands of Cebu and Panay. On the island of Marinduque quartz veins with auriferous pyrite and silver-lead deposits are being developed. On the island of Panaon, just south of Leyte a mine was worked to some extent during the Spanish régime but has not been reopened since the insurrection. Becker,[1] quoting from a manuscript report by Ashburner, states that there are here several quartz veins, one of which is two meters in width, carrying pyrite, galena and zinc blende, with gold values of $6 or $7 per ton.

The interior of the great island of Mindanao is not yet in a state to allow of prospecting, but promising placer fields are known to exist in Misamis and Surigao. Abella[2] studied the Misamis deposits in 1877 and stated that there are both bench and valley placers, small and discontinuous, but in places exceedingly rich, his assays often showing values of from 3 to 6 grams per cubic meter. The gold is derived from the quartz veins of Pigholugan, some distance inland. As described by Nichols[3] the Pigholugan region consists of slate and serpentine. Three systems of very narrow quartz veins traverse the region and at their intersections rich pockets are found.

[1] *Loc. cit.*, p. 581.

[2] Abella y Casariego, Enrique, "Memoria acerca de los criaderos auriferos del segundo distrito del departmento de Mindanao, Misamis," *Bol. del Com. del Mapa Geol. de España*, Madrid, 1879. English translation by W. D. Smith. *Min. Res. of the P. I.*, Manila, 1910, pp. 63–71.

[3] Nichols, J. C., "Notes on the Pigholugan and Pigtao Gold Region, Island of Mindanao," *Trans. Am. Inst. Min. Eng.*, Vol. 31, pp. 611–616, 1901.

In 1907 the deposits in the vicinity of Placer Bay on the Surigao Peninsula were visited by Goodman.[1] He found the prevailing country rock to be andesite cut by a series of narrow quartz veins, often not exceeding a centimeter in width, running in general about N. 55° E. Some of the richer of these stringers have been mined in a small way by natives. The placer ground derived from these veinlets is worked to some extent by the natives by means of crude sluices. Goodman considers this region a very promising field for hydraulic mining as rough tests showed values of over $1.00 per cubic meter.

GENERAL CONDITIONS.

To anyone who has seen the rapid development of mining camps in America or Australia, progress in the Philippines must seem insignificant. In the first place it must be remembered that in the Philippines travelling is difficult and slow. Communication between the different islands, while now in a fairly satisfactory state, was very uncertain in the early days, and prospecting in the jungle is extremely difficult work and requires a greater outlay than the average prospector is able to secure. Nowhere in the Philippines is there a poor man's country, where the prospector can wash enough gold to cover his expenses, as the natives, everywhere clever at panning, have skimmed the cream off of whatever very rich surface deposits once existed. Until recent years it has been almost impossible to secure sufficient capital for even the best propositions, owing in part to the uncertainty in regard to the political future of the islands, which held back investors from everything Philippine, but chiefly to the provision in the Philippine mining law, which attempts to limit the number of claims held by one owner. Section 33 of the Act of Congress of July 1, 1902, limits the locator to the possession of one claim on each lode, a provision which, were it not for the fact that it is absolutely impossible of enforcement, would be the death blow to Philippine mining. In other respects our mining

[1] Goodman, M., "The Gold Fields of the Surigao Peninsula, Mindanao," *Min. Res. of the P. I.*, Manila, 1909, pp. 40–44.

laws are excellent. A lode claim is 300 meters square with vertical side and end lines, doing away with the confusion resulting from extralateral rights, with provisions for assessment work and patent similar to the American law.

The labor question is becoming more serious. The Filipino, while possessing many good qualities, cannot be regarded as an efficient laborer. Chinese labor is absolutely excluded by law, and white manual labor is impossible in a tropical country. The recent increase in Philippine industry, following more settled conditions and the general belief in the permanence of American occupation, has created a great demand for native labor, and consequently there has been a considerable rise in wages without any increase in efficiency. Indeed, increased wages often make for loss of efficiency, as the Filipino, when he consents to work, works to gain money for a definite end, whether it be for the cock-fight, or for the purchase of a game-cock, carabao, wife, or other luxury, and when this is attained, retires until he feels the necessity for something else. On the other hand, the native is quick and willing to learn, and the ignorant peasant, who in his first day's work tries to carry his wheelbarrow on his head, will soon, if handled with patience and firmness, develop into a fairly capable miner, who takes great pride in his work. At present the wages of ordinary labor vary in different camps from forty to sixty cents per day, and of miners from fifty to eighty cents, but it must be remembered that aside from the inefficiency of the individual, the added cost of the closer superintendence required, makes the cost of work done higher than in America. In all the districts a limited number of Japanese carpenters and timbermen are employed. These are never found to be as satisfactory as Chinese and command wages of from ninety cents to two dollars per day. Native laborers always do best when housed and fed by the employers. As their food consists exclusively of rice and fish, a native is well fed at a cost of from six to ten cents per day. As a skilled laborer the trained native does excellent work, and native blacksmiths, engine drivers, chemists and draughtsmen are splendid workers in their lines, when in

subordinate positions, where they can fall back upon the white man for advice and assistance when new conditions confront them. In positions of responsibility, even the best trained native is incompetent, as his lack of initiative makes him helpless, while his conceit is always bringing him into difficulties. The different tribes vary somewhat in their quality as laborers. The Christian tribes make steadier workers, though less trustworthy than their mountain brothers, and the Ilocanos and Visayans are preferred to the Tagalogs.

Except for the labor question, affiairs in the Philippines are in a very satisfactory state. The insular government is doing whatever is possible to aid commercial and industrial development. Good roads are being built and maintained, on the larger islands railroads have been built under government guarantee, and the inter-island transportation service has been made efficient under a wisely planned system of government subsidies. The services of the members of the various government bureaus, particularly those of Science (including the Division of Mines), Agriculture and Forestry, are always at the disposal of the intending investor. There is a government assay office connected with the Division of Mines, where commercial assaying is done, and assays are made free for prospectors in undeveloped districts. An ore testing laboratory is planned where runs of ore will be made at cost, relieving miners from the long delay involved in sending test shipments of ore to America or Australia. At present, while mining engineers are so scarce in the islands, arrangements have been made, whereby the services of one of the staff of the Division of Mines can be secured for private work or surveys. In addition to this is, of course, the regular geologic and topographic work of the division, the results of which are published in Section A of the *Philippine Journal of Science,* and the annual bulletin of the "Mineral Resources of the Philippine Islands."

THE OCCURRENCE OF OIL AND GAS IN THE SOUTH MIDWAY FIELD, KERN COUNTY, CALIFORNIA.

WILLIAM FORSTNER.

Our knowledge of the constituents of petroleum, especially in regard to the gaseous constituents, is as yet rather vague. It is generally believed that petroleum is the decomposition product of deeply buried organic matter, yet our understanding of the different stages through which this process passes, of the paragenesis of the different products is still to a large extent hypothetical. We are not able to carry out the process under the identical conditions under which it takes place in nature, conditions which also differed in the various localities where accumulations of oil and gas are found at present. The behavior of the hydrocarbons is another difficulty in tracing the actual course of events. It is not within the limits of this article to enter more fully in this question, which belongs more particularly to the realm of chemistry but there is, however, one point to which attention will have to be called, namely the association of gas with oil.

Petroleum is not a homogeneous substance, but a mixture of hydrocarbons, belonging to various series, each of which consists of a number of distinct hydrocarbons, wherein the ratio of carbon and hydrogen forming the hydrocarbon molecule remains the same, but the number of atoms of carbon and hydrogen forming the molecules is different. In such series the molecules containing the smallest number of atoms of the two elements form volatile hydrocarbons; as the number of atoms increases the hydrocarbons become liquid, and by further increase of that number solids are formed. The relative amount of the hydrocarbons of different series contained in a petroleum depends upon the conditions under which it was produced.

The hydrocarbons of these series are easily dissociated, forming at one end marsh gas and natural gas; then intermediate fluids, petroleum of various gravities; then viscous and elastic hydrocarbons; and finally solids at the other end. The refining of crude oil is based on the dissociation by heat, fractional distillation. This same fractionation takes place, to a certain degree, mechanically when oil passes through 'fuller's earth. Water has also the power to further dissociate the petroleum.[1]

During the originating of the petroleum by the decomposition of organic matter in the shales, different conditions of heat and pressure occur, and no doubt already at that stage, gaseous hydrocarbon compounds and petroleum of various specific gravity are formed. Natural gas and petroleum are both products of the decomposition of the organic matter, their weight and other attributes depend upon the conditions under which the decomposition takes place.[2] C. Engler in discussing the origin of petroleum and the different stages of the process, states that during the last stage there occurs "the formation of the liquid hydrocarbon mixtures of the oil by a violent reaction, which causes the splitting up of complex intermediate products with the formation of gaseous products." He adds that this change must have taken place at a high temperature, and at great depth.[3] The association of oil and gas has also been observed in many wells of the gulf coast plain.[4]

In approaching the surface, petroleum is exposed to new agencies which modify it to a greater or less extent. Water, especially hot, oxygenated water, exerts a strong chemical influence on these hydrocarbon compounds, the free oxygen promoting the formation of the lighter hydrocarbons, and restricting that of the heavy hydrocarbons.[5] Bacterial decomposition

[1] D. T. Day, Bulletin U. S. Geological Survey, No. 365. J. E. Gilpin & M. P. Cram, *American Chemical Journal*, Vol. 40, 1909, p. 495.

[2] J. E. Gilpin & D. E. Brausky, *ibid.*, Vol. 44, 1910, p. 251. W. J. McGee, Eleventh Annual Report, U. S. Geological Survey, Pt. 1, p. 614.

[3] *American Chemical Journal*, Vol. 41, 1909, p. 71.

[4] Hayes & Wm. Kennedy, Bulletin U. S. Geological Survey, No. 212, pp. 154 and 155.

[5] A. B. Davis, *Mining and Scientific Press*, February 5, 10, p. 219.

may also influence the production of those compounds. It has been shown that the volatile hydrocarbons in the oil shales of the upper Mississippi valley are either directly or indirectly caused by microscopic algæ.[1] Peckham has ascertained the presence of maggots in a petroleum found in California, and ascribes to them the high percentage of nitrogen in those oils.[2]

The formation of these bituminous hydrocarbon mixtures, and their accumulation into globules in the shales, cover a long geological time, during which disturbances in the strata have caused different temperatures in different parts of the shale measures wherein these processes took place, especially when these structural disturbances were caused by irruptive action.

The hydrocarbon compounds are gradually squeezed out of the fine-grained shales, and migrate into the adjoining more porous sandstone strata. Although we generally refer to the shales and clays as impervious, it must be borne in mind that even in the shales the pore spaces average not less than six per cent.[3]

The channels through which the gases and liquids move are: the interstices between the grains of the rock, and the contacts of the planes of stratification, fracture, etc.

The interstices can be divided into three classes: Openings larger than those of capillary size, capillary openings, and openings smaller than those of capillary size, subcapillary openings. Supercapillary openings are found in bedding and joint planes, in coarse sandstones, and in conglomerates. In these openings the flow of liquids is controlled by the ordinary laws of hydrokinetics, modified by the viscosity of the fluid, and the regularity, size and length of the opening. Capillary openings include the great majority of the interstices between the grains of sands and sandstones, many of those in conglomerates, and many of the openings caused by fracture. In these openings the velocity of flow depends upon the area and cross section of the opening, its length, and the viscosity of the fluid. The movement is so slow

[1] H. Foster Bain, Bulletin U. S. Geological Survey, No. 294, p. 26.
[2] *American Journal of Science*, series 3, XLVIII., 1894, p. 250.
[3] M. J. Munn, Economic Geology, Vol. IV., p. 516.

that the friction of the moving fluid over the sedimentary film is very small, especially in long openings. Subcapillary openings include part of the interstices in coarser sediments having capillary openings, and nearly all the interstices between the grains of clays, shales and slates. The movement of the fluid in these openings is excessively slow, under the hydrostatic pressures generally occurring in those strata the movement will be reduced to such an extent, that the fluid may be considered as fixed films held by molecular attraction.[1]

The pressure exercised by the gaseous hydrocarbons probably helped the process of migration of the liquid compounds out of the shales. Gases under high pressure and at high temperature do not adhere strongly to the walls of subcapillary openings, and have small viscosity. Consequently they pass more readily through these openings.

The clay and the shale derived from it always contain water in their subcapillary interstices, entrained therein during their process of formation.

The oil is originated in the clay beds during the time that the latter are forming at the bottom of the sea, and due to the great attraction of oil for clay, the globules of oil, as they form, attach themselves to particles of clay and thus form a petroliferous mud. The migration of the water and oil out of these muds took place during the compression of the clays, which transformed them into shales, under conditions of compression and increased heat. The overlying sandstones in which the oil and water from the shales accumulated, participated in this compression, and the water being less viscous than the oil, the ratio of oil to water was increased in the sandstone. That the oil and gas was not diffused throughout the entire sandstone strata can be explained by assuming that the capillary and subcapillary interstices of the surrounding fine-grained, and partly cemented sandstones, and of the shales were filled with water, thereby completely sealing up the oil and gas in the more porous portions.[2]

[1] M. J. Munn, Economic Geology, Vol. IV., pp. 519–527.
[2] C. R. Van Hise, Monograph U. S. Geological Survey, No. 47, pp. 129–146.

Within the porous strata, forming the productive horizons, we then have tabular lenses, or possibly strata, of fine-grained and relatively barren sandstones, others of clay and shales, and others of coarser sandstones and conglomerates generally carrying oil and gas, exceptionally carrying water.

As already stated, gases have probably been formed contemporaneously with the oil; volatilization of the liquid hydrocarbons is steadily going on, and is increased in presence of oxygenated atmospheric water. It must be remarked that watersands are only found occasionally in the productive oil horizons, but are generally found immediately underlying. Natural gas, the gaseous hydrocarbon compound, is a more simple and stabler product than petroleum, and consequently when it is once formed will not again change into the latter. In a sealed oil horizon the natural gas will steadily increase, although the rate of increase may be very slow. When exposed to the air during a sufficient time, all the hydrocarbons which in distillation go over at temperatures below 300° C., are evaporated.[1] When the oil pools are surrounded by surface waters carrying some free oxygen, it appears to me rational to assume that the same process occurs, although to a less extent, and depending largely on the amount of free oxygen carried by the surrounding water.

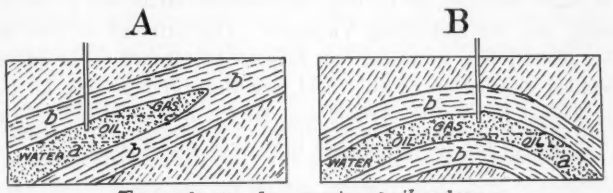
The gas moving with greater ease through the rocks, and being of lighter gravity than the oil, will under ordinary circumstances gather at a higher level than the oil, and where little or no watersands are present, there will be an upper subzone containing gas accumulations, and a lower subzone containing oil accumulations. These accumulations will take place in the tabular lenses of coarser sandstones and conglomerates; as the sandstones become finer and more indurated their bitumen content decreases, until in the finest and hardest sandstones, as in the clays and shales, the amount is generally so small that they are considered barren.

This "anticlinal" theory, or as proposed by F. G. Clapp, the "structural"[2] theory of the accumulation of oil and gas is gen-

[1] Chas. F. Mabery, *American Chemical Journal*, Vol. 33, 1905, p. 276.
[2] Economic Geology, Vol. 5, p. 505.

erally accepted, and has in numerous cases been confirmed by the experience in the field. It has been discussed in so many publications that it will suffice to give the following sketch, which offers a graphic representation of its conclusions.[1]

The structural theory then assumes that the gas will accumulate above the oil, and that both are under the same hydrostatic pressure. The question now arises, can these assumptions ac-



Types of natural reservoirs of oil and gas.

A *Inclined bed of sandstone (a) sealed in by shale (b) but somewhere in communication with water under hydrostatic pressure.*

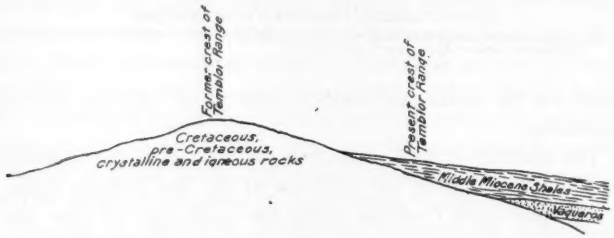
count for the conditions found to exist in the Midway field of California.

The Midway oilfield, California, is located in the southern part of the oilfield on the west side of the San Joaquin valley, which runs from Coalinga south for a distance of over one hundred miles, along the east slope of the Mount Diablo range, and nearly abuts to the south against the Tehachipi range, which encloses the San Joaquin valley to the south. It lies between the McKittrick field to the north, and the Sunset field to the south, covering the portion lying between the line dividing Townships 30 and 31 S., M.D.m., and the south line of Township 32. The southern portion of the field is called the South-Midway field.

That part of the Mount Diablo range which runs along the western border of this field is known as the Temblor range. The main ridge and the upper part of the east flank of the Temblor range is covered by a thick, strongly folded belt of middle Mio-

[1] Bulletins U. S. Geological Survey, No. 238, p. 46, and No. 296, p. 20.

cene shales. The lower portion of this belt consists of siliceous and clayey shales, the upper third of diatomaceous shales, both intercalated with prominent lenses of coarse sandrocks. The underlying lower Miocene, Vaqueros, sandstone appears only at the surface on the west flank of the range. The oil is believed to have originated in the middle Miocene diatomaceous shales, and to have migrated partly into the sandstone lenses within the shale measures, partly into the overlying sands, and probably partly into the underlying Vaqueros. The latter oil horizon in this district lies, however, too deep to be reached. For more detailed description of this field, see Bulletin No. 406, U. S. Geological Survey, R. Arnold and H. R. Johnson, from which a number of the following data have been compiled.


Former crest of Temblor Range
Present crest of Temblor Range
Cretaceous, pre-Cretaceous, crystalline and igneous rocks
Middle Miocene Shales
Vaqueros

The lower part of the east flank of the range is covered by the upper Miocene-Pliocene-Pleistocene McKittrick formation, wherein the commercially available oil horizons of this district are contained. This formation is unconformable with the underlying middle Miocene shales, dipping less steep to the northeast. It consists of a series of gravels, clays, shales and sands. The sands and gravels carry water, oil, tar and gas; the individual beds and lenses being separated by more or less important partings of clay and shale. The watersands are distributed throughout the formation, and are found at different levels, above, within, between and close to the two oil horizons hereinafter more specifically described. They vary in location within the

strata in various sections of the field, as also the composition of the water, which generally speaking is strongly mineralized, especially in the lower strata.

Two prominent oil horizons have been differentiated within the McKittrick formation. It must not be understood that these horizons or zones represent solid strata of oil bearing sand. They consist of strata of sandstone of varying texture, intercalated with shale and clay, and these individual sandstone strata are not persistent, but tabular in form. They are not all bitumen bearing, some being barren; occasionally water sands are found in the oil horizons, especially in the upper zone; others carry oil, gas or tar. The varying characters of the sands in the oil zones are due, partly to the difference in texture, partly to the difference in the general conditions of structure prevailing in the various parts of the field. The zones are limited by more prominent beds of clay and shales, one overlying the upper zone and one separating the two zones.

The Upper Zone—Zone A.—This zone is overlaid by a shale belt. It consists of gas, tar and oil sands, and occasionally some thin beds or lenses of watersands, interbedded and separated by thicker beds of clay and shale. In the Midway field, except in a part of its southern portion, this zone always contains sands carrying oil in commercial quantities.

Underlying Zone A is a belt of blue or brown shale, from 30 to 200 feet thick, in places containing beds or hard sands, and intercalated watersands; these shales separate zone A from the underlying horizon.

The Lower Zone—Zone B.—which is the principal productive zone. It lies at the base of the McKittrick formation, and rests directly on the middle Miocene shales. Its thickness varies from 10 to 800 feet. In its thicker parts there are a number of productive sands intercalated with beds of barren sands, and shales. The sands vary from medium to coarse, with pebbles and cobbles. The finer-grained sands are generally quartz sands; the pebbles and cobbles are principally derived from granitic or other crystalline rocks. In the Sunset field there are besides pebbles of dia-

base, quartzite, and black slate. The composition of these sandstones indicate that at the beginning of the upper Miocene the crest of the Temblor range was to the west, and at a much higher altitude than the present range; and was formed by rocks of Cretaceous and pre-Cretaceous age. This crest was not only eroded during the upper Miocene and later periods, but must have sunk below the present level of the range, forming northwest-southeast fault lines along the west slope of the present range, thus explaining the surface exposures of the Vaqueros at the present foot of that slope.

The occurrence of heavy shale beds above zone B, the quartzose sands in zone A, overlaid by another belt of shales, and the foldings in the McKittrick formation indicate strong, subsequent oscillations, combined with structural disturbances.

The west line of the developed territory in the south part of the Midway field runs about from the northwest corner of sections 36, T. 31–22 in a general southeastern direction through this section, thence through sections 6, 8, 17, 21, 22, 26 and 25 of T. 32–23, and section 31, T. 32–24. Along this line the depth of the top of zone B below the surface is at the northern end 1,600 feet, rapidly decreasing in that section to 800 feet going southeast, and remaining at this elevation to about section 22, and then gradually increasing until in the southeast corner of section 31, T. 32–24, it is again 1,600 feet below the surface.

From this line the top of zone B, as far as yet developed, dips to the northeast at an angle of about 16°, while the surface dips only 1° 30′ to 2°, bringing the top of zone B deeper below the surface as we go eastward.

The condition under which the oil and gas exist within this zone in the south Midway field, can be briefly stated as follows. In sections 7, 8, 9, 16, 17, T. 32–23 the gas pressure is very slight; it increases somewhat in sections 14, 15, 21, 22 and 23 of same township, causing some sand to accompany the oil, but not strong enough to force the oil to the surface and make flowing wells. This pressure further increases in sections 24, 25 and 26 of same township, and in the southern part of section 25 the New

Richmond well yielded when first drilled, sufficient gas to be used at the time. To the southeast, in sections 30 and 31, the gas pressure was apparently of no great importance. To the north, in section 6, T. 32–23 and in sections 22 and 36, T. 31–22 the wells give evidence of strong initial gas pressures. To the east the gas pressure increases considerably, causing the oil to flow over the top of the casings in many instances with such a force as to cause gushers.

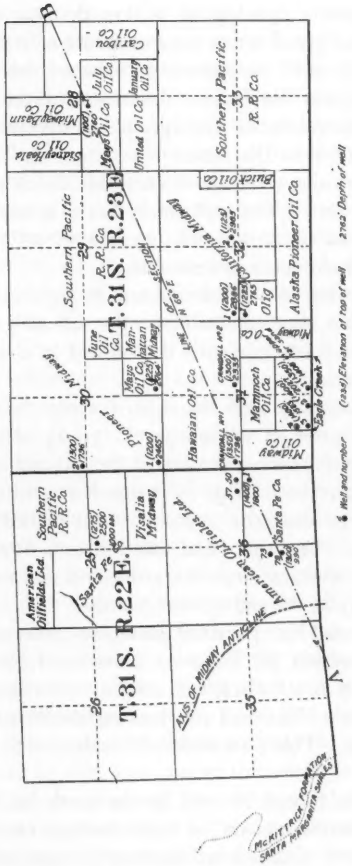
The productive zone, B, at the base of the McKittrick formation may be considered as belonging to the lower part of the Upper Miocene. During the later geological periods a number of successive subsidences and elevations of the territory took place, accompanied by structural displacements, causing folding of the strata, and thereby creating channels along which the fluids and the gases could circulate more freely than along the interstices between the grains of the rocks. The clays and shales generally yielded to the pressures by plication, the sandstones more by fracturing. This zone was buried far deeper than at present for a large portion of the time elapsed since its formation. The bitumen was squeezed out of the clays during those periods of great pressure, contemporaneous probably with the period wherein these were altered into shales. The greatest pressures were exerted close to the axes of the anticlines and synclines, and here the fissuring of the brittle sandstone increased the conditions favorable to the circulation of the bitumens, but at the same time allowed the access of atmospheric, oxygen carrying waters, thereby increasing the conditions favorable for the formation of natural gas, as above mentioned. Near the axes of the anticlines we should find much gas and oil of lighter gravity. The water will by its gravity slowly reach the lower levels in the porous strata and accumulate toward the axes of the synclines, leaving the petroleum and the natural gas predominately above its level. The earth's movements have, however, not been regular, and there is reason to believe that during the long lapse of time from the upper Miocene to the present, the structural formation has often varied. In fact the present status is the result of accumulation

and dissemination during a great number of centuries under constantly varying conditions.

Within the tabular lenses wherein the gas and oil accumulated the evaporation of the oil continued. If petroleum was a homogeneous liquid this evaporation would continue until the pressure of the gas had reached the vapor pressure at the existing temperature. But due to the heterogeneous character of the petroleum, and to its tendency to dissociation, it can only be stated that this evaporation continues until a status of equilibrium has been reached. This implies that the gas pressure is not sufficient to force the water out of the capillary and subcapillary openings of the strata surrounding the locus of accumulation. It is impossible to state the pressure required in this case, because according to the formulas of capillary flow the length of the channels and their form are controlling factors, and both are continuously varying throughout any stratum. Assuming a gas pressure of 1,000 pounds per square inch, the largest diameter of capillary openings, with a straight channel through one hundred feet of sand strata, and a temperature of 80° F., the gas pressure would be held in equilibrium by a hydrostatic pressure of 2,000 feet, without taking into consideration any friction resistance in the latter column. As the flow of water through capillary openings is greatly reduced by the variations in cross section of those openings, it is readily seen that the sealing of the oil and gas accumulations by the water filling the interstices of the surrounding strata is complete at a much shallower depth.

It may be that in these portions where heavy pressures exist, from 600 to 1,000 lbs. per square inch, the gaseous hydrocarbons have been compressed into liquid form.[1] If this view is correct, the pressures which caused the liquefaction of the gas must have been greater than the vapor pressure, and must have occurred subsequent to the formation of the gas. They must have been caused by a compression of the strata, which reduced their interstices, probably accompanied with induration, of at least a part of them, by cementation. That such can have occurred after middle Miocene times is very probable.

[1] Courtenay De Kalb, *Mining and Scientific Press*, June 11, 1910, p. 857.



Map of portion of Midway Field

FIG. 16. Map of Portion of Midway Field.

The hydrostatic pressure, sufficient to seal up the gas and oil must, however, be considered as a passive resistance, and is not capable of active energy. The velocity of the flow of the water through the capillary openings is so slow that the water cannot replace the oil and gas at a rate commensurate with its extraction.

A brief summary of the history of some of the wells will be necessary to explain the further discussion of the behavior of the water, oil and gas in the underground reservoirs.

The Mays well, near the center of sections 28, T. 31–23, elevation 1,100 feet above sea level; came in March 1, 1910, at a depth of 2,760 feet. The well broke loose a week later, and flowed at the rate of 50,000 bbl. per day of 27° B. oil; then choked up and broke loose at intervals.

A strainer was put in and the well was brought in as a regular producer on July 2, flowing steadily at the rate of 3,500 to 4,000 bbl. per day, which has gradually diminished to about 1700 bbl. at the end of October.

The Pioneer-Midway well No. 2, in the southwest corner of the northwest quarter of section 30, T. 31–23, elevation 1,300 feet above sea level; reached the top of the oil sand at a depth of 1,796 feet in May, 1909. This well went 8 feet in the sand and was a moderate producer on pump. It was drilled deeper into the sand in September, 1910, and came in as a flowing well on October 9. The well was kept in control and was making about 1,450 bbl. per day at the end of that month.

The Santa Fe well No. 4,[1] in the northeast corner of the southeast quarter of section 36, T. 31–22, elevation 1,400 feet above sea level; came in as a flowing well on July 22, 1910, at a depth of about 1,800 feet. The well was making about 10,000 bbl. per day on August 3. This flow suddenly increased to 30,000 bbl. per day.

American Oilfields well No. 79, on the south half of the east line of the southwest quarter of same section, elevation 1,500 feet above sea level; was finished on May 5, 1910, at a depth of 990 feet, making 1,000 bbl. per day of 23° B. oil, with 112 feet

[1] Shown on Figs. 16 and 17 as No. 1.

of oil sand in bottom. From May 5 to July 25 the yield gradually increased to 3,000 bbl. per day, and from July 25 to August 4, except one day when the well was sanded, it flowed from 8,000 to 10,000 bbl. per day. On August 5 it averaged at a rate of 15,000 bbl., on August 6 and 7 average flow 16,000 bbl., reaching 20,000 bbl. on August 8. It sustained this rate until the first days of September, then decreased somewhat and yielded at the end of September 18,000 bbl. In the beginning of October it yielded 14,000 bbl., and at the end of that month 5,000 bbl. per day, being considerably choked up.

The following will indicate the pressure upon the oil in the oil reservoir required to account for the behavior of the Mays well: 50,000 bbl. of 42 gallons, per day = 0.58 bbl. per second = 3.248 cu. ft. The area of the casing, 4½ inch diameter, is 0.11043 sq. ft.; the velocity of the oil was therefore 29.4 feet per second. The viscosity of this oil (27° B.) is about 3. We then have a column of oil of 2,760 feet, with a specific gravity of 0.896, moving upwards at a velocity of 29.4 feet per second. The weight of this column is 1,070 lb. per square inch. The friction and the viscosity represent an added weight of 195 lbs. per square inch, making a total pressure of 1,265 lbs. per square inch. As this column moves at a velocity of 29.4 feet per second the work done is equal to 37,191 foot-pounds per second. In reality the work is much greater, as a great quantity of sand, pebbles and cobbles are ejected with the oil. The hydrostatic pressure can only be figured from the outcrop of the lowest McKittrick sandstone, which overlies the thick strata of middle and lower Miocene shales. The elevation of this outcrop is about 2,000 feet above sea level, 3,660 feet above the bottom of the well. The hydrostatic pressure may be assumed equal to that produced by this head, under the conditions of rest existing at the moment that the well bore enters the reservoir, as in the exceedingly slow movements of the groundwater the viscosity and the friction in the capillary channels become almost zero. The hydrostatic pressure would then be equal to 1,582 lbs. per square inch. When the well flows for a certain length of time conditions become different.

50,000 bbl. of oil represent 286,000 cu. ft.; the saturation of the sand is certainly not over 20 per cent., and not all the oil is extracted from the sand, consequently the oil of at least 1,430,000 cu. ft. of sand is extracted per day. Assuming a maximum thickness of the sand of 300 feet (as far as known no such thickness of an oil sand has been found in the Midway field), this represents 4,766 sq. ft. of sand from which the oil has been extracted per day. If this oil was under the hydrostatic pressure of the surrounding water, this water must, to some degree, have invaded this territory and would at least partly accompany the oil further emitted from the well.[1] If the water is to invade the space vacated by the oil, the speed of flow would become very appreciable, and the friction resistance would in that case increase very rapidly. The hydrostatic pressure is not sufficient to force the water through the capillary and subcapillary openings of the impervious strata at a velocity required to replace the oil as it is withdrawn, and consequently if the movement of the oil were dependent upon that pressure, the wells could flow but a very short space of time. The persistence of the flow indicates then that the pressure on the oil must be caused by gas, which, according to the structural theory, accumulates in the upper portion of the reservoir.

American Oilfields well No. 79 was finished with 12½-inch casing, and flowed for 30 consecutive days at the rate of 20,000 bbl. per day, or 1.288 cu. ft. per second, at a velocity of about one foot per second. The specific gravity of this oil (22° B.) is 0.924, and the weight of the column of oil is 395.5 lbs. per square inch. The viscosity of this oil is about 11, and the friction resistance will represent a pressure of 226.5 lbs. per square inch, making the total pressure 622 lbs. per square inch. The bottom of the well is at 500 feet above sea level, or 1,500 feet below the outcrop of the McKittrick sands; the maximum hydrostatic pressure is then 648.8 lbs. per square inch.

We may assume that prior to the entering of the well bore

[1] J. F. Carll, Seventh Report on the oil and gas wells of western Pennsylvania.

into the reservoir a condition of equilibrium existed. If the gas was under a pressure much higher than that of the water in the strata sealing up the reservoir it would force this water back until the gas occupied such a volume that its pressure would be equal to the hydrostatic pressure plus the friction resistance within the channels of those strata. In well no. 79 the pressure was relatively low for the first 81 days, and then within 16 days increased to its maximum. It must be further noted that the increase in pressure was simultaneous with the coming in of Santa Fe well no. 4, located one half mile to the northeast, and that in this well the pressure was greater than in no. 79, but smaller than in the Mays well. This latter well, Crandall no. 1, Santa Fe no. 4, and American Oilfields No. 79 are located nearly in one line, running from the last named well N. 67° E. The accompanying sketch gives a graphic representation of the situation. According to the structural theory the gas should have accumulated near the upper or southwest end of the oil horizon. It might be argued that these wells are not located on one reservoir, but the fact that the Pioneer-Midway wells and the Mays well in section 30, as also the California-Midway and the Eagle Creek wells in section 31, both of T. 31–23, are all producing,

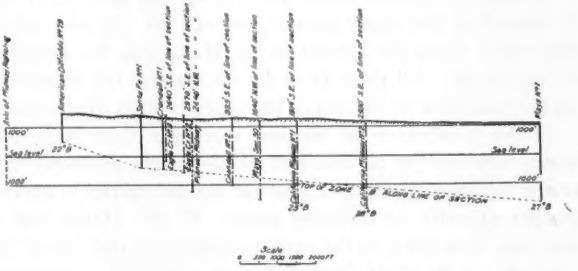


FIG. 17. Section on Line A–B of Fig. 16.

indicates a continuous oil horizon, although this must not be accepted as stating that there is one continuous stratum of oil sand. I have indicated these wells on the section, with the distance they are located from the line along which the section was taken.

According to the structural theory the main accumulation of gas would have to be found near American Oilfields well no. 79. This well yielded in the first 81 days 81,000 bbl., representing 453,600 cu. ft. Assuming the high saturation of 20 per cent., this represents an extraction from at least 2,268,000 cu. ft.; as the thickness of the oil sand is 112 feet this represents an area of 20,250 sq. ft., or 450 feet square. The subsequent increase in production was simultaneous with the bringing in of Santa Fe well no. 4, and the behavior of the two wells would indicate that the conditions, under which the oil was in the loci from which they respectively drew their oil, were similar and governed by the same cause. The suggestion is therefore justified that if the pressure was caused by accumulated gas, this gas could freely act in the intervening territory. It must be further noted that the pressure in the Santa Fe well was greater than in no. 79. The pressure in only one well of this vicinity is known to me, namely in Eagle Creek no. 4. At a depth of 630 feet the gas pressure was 780 lbs. per square inch, and in August of this year drilling was suspended on this well on account of this heavy pressure, which is lower than the closed pressure under which the gas is in the reservoir.

It must be further noted that the specific gravity of the oil is highest in the upper portion, at well no. 79, and gradually diminishes being the lightest in the Mays well, the deepest well in section 28. All these facts do not confirm the hypothesis of an accumulation of the gas in the upper portion of the reservoir.

In the productive oil horizon there are then large tabular lenses, wherein the oil accumulates under gas pressures varying in the different parts, and wherein the oil carries a greater or smaller quantity of occluded gases. C. W. Hayes and Wm. Kennedy have come to the same conclusion in their study of the oil fields of the Gulf Coastal Plains, where the association of gas with oil is as marked as it is in the Midway field.[1] Within each individual pool the material varies in coarseness, and the gas pressures will vary in its different parts. When by the com-

[1] Bulletin U. S. Geological Survey, No. 212, p. 156.

pletion of some wells in such a pool the oil therein starts to move, the gas pressures will find occasion to be equalized, and if the wells reach the pools in a portion where the gas pressure is low, it is reasonable to suppose that it will increase after a lapse of time, as the movement of the oil towards those wells will create channels through which the gas can accommodate itself to the tendency of equalization of pressure.

That the wells formerly drilled along the west side of the South Midway field showed no gas pressure is explained by the fact that these wells are located close to the axis of the Spellacy Hill anticline, as the fissuring of the strata along this axis allowed the gases to escape when under high pressure.

THE IRON FORMATION OF THE CUYUNA RANGE.[1]

FRANCIS S. ADAMS.

THE ORES.

GENERAL DESCRIPTION.

The Cuyuna ores fall into two main groups, hard and soft ores.

The soft ores are black, brown and reddish hydrated hematites, with large pore space and much like the soft ores of the Penokee Gogebic district. These soft ores are of three types, a high grade limonite ore running between 55 and 63 per cent. Fe, and of a brown to very dark color; a high grade red hematite averaging 63 to 66 per cent. Fe and about .04 per cent P, and a lean, reddish, purple ore running between 45 and 50 per cent. Fe, not so soft as the first type. This last is easily broken down with a pick, but retains its stratified form and hangs together in fairly large pieces. Cherty layers are scattered through the mass at frequent intervals, the cherty impurity probably accounting for the low grade.

The hard ores are of two types. The bulk of the hard ore is a black to very dark brown hydrated hematite. It is closely stratified and has suffered brecciation due to slumping, caused by the leaching out of silica. In the main it is high grade, running from 50 to 60 per cent. Fe. Although brecciated, it holds together in large masses due to the partial cementing of the brecciated pieces by the secondary introduction of iron. The Cuyuna hard ore is much softer and more limonitic than the dense steel blue hematite of the Vermillion range.

The other type of Cuyuna hard ore, relatively small in amount compared with that described above, is a hard blue hematite, massive and unbrecciated, running about 58 to 63 per cent. Fe. This is a true hard ore and can only be drilled with diamonds.

[1] This paper was written in 1909.

It occurs in layers in the softer ores and is most frequently found close to the intrusives.

It is impossible to state, at this incomplete stage of exploration, the relative proportions of hard and soft ore. The soft ores probably form the larger part; but the hard ore may occur in a much larger percentage than has previously been supposed.

Chemical Composition of the Various Types of Ore.

Average Hard Ore.—The average composition of the hard ore of the Cuyuna range is as follows:

SiO_2 = 8.07 per cent.	P = 3.67 per cent.
Al_2O_3 = 1.00 per cent.	Accessory constituents = 1.02 per cent.
FeO = 3.11 per cent.	
Fe_2O_3 = 79.00 per cent.	Iron = 57.5 per cent.
H_2O+ = 6.45 per cent.	

The above is an average of the massive hard blue hematites and the limonitic, brecciated hard ores.

Average Soft Ore.—Below we have the analysis of the average soft ore of the district. The sample for this analysis is made up from 125 feet of drilling from three scattered holes in soft ore.

SiO_2 = 7.07 per cent.	Accessory constituents = 1.00 per cent.
Al_2O_3 = 5.61 per cent.	
FeO = 76.85 per cent.	
Fe_2O_3 = 3.06 per cent.	P = 2.83 per cent.
H_2O+ = 6.34 per cent.	

Analyses of Drill Holes in Ore Showing the Chemical Relations of the Varying Ores Encountered in Drilling through a Deposit.

The following table shows the chemical analyses for a drill hole in ore on section 21–46–28. As one follows the analyses the changes in chemical composition are well illustrated as the ore becomes leaner, finally grading into a ferruginous chert.

Note the direct variation between the iron and silica content as iron goes out and silica increases. The other constitutents remain practically the same throughout.

Footage.	Iron.	Phos.	Mang.	SiO_2	Al_2O_3	CaO	MgO	H_2O+
175–180	58.07	.519	.24	4.86	.68	.11	.08	7.34
180–185	59.73	.547	.22	3.23	1.13	.15	.14	
185–190	59.02	.425	.20	3.78	1.35	.10	.11	
190–195	59.11	.604	.20	4.10	1.25	.17	.10	7.83
195–200	60.32	.414	.40	6.35	.63	.10	.09	
200–205	59.60	.385	.51	7.22	.66	.08	.08	
205–210	59.44	.353	.36	7.34	.62	.11	.10	5.35
210–215	60.93	.264	.40	6.68	.49	.18	.07	
215–220	61.10	.229	.47	7.16	.44	.20	.05	3.36
220–225	57.82	.287	.44	13.00	.47	.10	.04	
225–230	57.93	.284	.40	12.96	.48	.17	.08	
230–235	55.52	.337	.43	15.19	.49	.16	.07	2.75
235–240	40.66		.94	9.72	2.00	.14	.06	
240–245	49.07							
245–250	45.67		.48	29.30	.35	.31	.09	2.18
250–255	46.82							
255–260	47.95		.40	26.04	.59	.10	.10	
260–265	48.74							
265–270	48.28		.52	26.00	.52	.16	.06	2.62
270–275	41.47							
275–280	41.80		.39	36.74	.54	.17	.08	
280–285	40.36							
285–290	36.80		1.12	32.56	.73	.42	.36	
290–295	37.19							
295–300	37.85		1.05	31.71	.74	.44	.37	7.11

Consideration of the Important Chemical Constituents of the Cuyuna Ores.

From a consideration of the average chemical compositions of the various types of the Cuyuna ores and of the foregoing analysis of drill holes in ore and ferruginous chert, several facts are brought out regarding the make-up of the ores and the characteristic behavior of certain elements.

Iron.—Ore has been found reaching 69 per cent. metallic iron and from this the iron content grades downward through the lean soft ores, averaging 45 per cent. Fe, to the ferruginous cherts averaging about 33 per cent. Fe. Counting as ore those portions of the Deerwood formation containing over 45 per cent. Fe, the average of all the Cuyuna ores now actually exposed by drilling would be in the neighborhood of 52 to 50 per cent. Fe.

Taking the average ore of the other Lake Superior ranges as calculated from the cargo analyses of all ore shipped from each range in the year 1909 we get the average Mesabi ore as con-

taining 58 per cent. Fe. The Marquette range averaged 57 per cent., the Menominee averaged 52 per cent., the Penokee Gogebic averaged 60 per cent. and the Crystal Falls and Iron River districts averaged 54 per cent. and 55 per cent. in metallic iron respectively.[1] The Cuyuna ores, then, as a whole, are not high grade. It is to be remembered however that the Cuyuna average is derived from analyses of drill cores, which generally show over 2 per cent. less iron than the cargo analyses.

Phosphorus.—The Cuyuna ores are almost all high in phosphorus, averaging about .346 per cent., and ranging from .958 per cent. to .023 per cent., for ore running 50 per cent. Fe or better. The ores in that part of the district lying southwest of Brainerd show rather high uniform percentages in phosphorus. The ores of the north range or Rabbit and Serpent Lake district appear to have the lowest phosphorus content.

The Crystal Falls and Iron River ores average higher in phosphorus than the Cuyuna ores.

Silica.—The silica content of the Cuyuna ores varies widely. For ores of 53 per cent. Fe or better the range is from 1.80 per cent. to 16.60 per cent., while 50 per cent. ore has been encountered running 24 per cent. SiO_2. Silica decreases as iron increases and vice versa. The average silica content for all Cuyuna ores of over 50 per cent. metallic iron is about 10 to 12 per cent. The analyses given for the average hard and soft ores of the Cuyuna, however, represent the average *standard grade* ores and not averages of all the possible ores of the formation.

Loss by ignition above 212° F.—Inspection of the foregoing analyses where loss by ignition was figured shows it to be fairly high for the Cuyuna ores. The average, for ores of 50 per cent. Fe or over, is about 6.40 per cent.

The Cuyuna ores are a trifle more hydrated and the proportion of limonite to hematite greater than the ores of the other Lake Superior ranges.

Alumina.—Alumina shows quite a variation, according to the

[1] All analyses of ore taken on samples dried at 212° F.

degree of slatiness of the ore; but averages about the same as in the Mesabi, Penokee-Gogebic or Menominee range ores.

Manganese.—The average manganese content for the Cuyuna ores is not at all high. In certain holes, notably in the Rabbit Lake vicinity, ores are encountered running quite high in manganese, up to 10 or 12 per cent. The manganese is higher in the surface ores than at depth. One hole in the iron formation showed a manganese content reaching 28 per cent. The iron content in this hole was low, however, averaging in the thirties.

Mineralogical Composition of the Various Types of Ore.

Under the microscope we find the Cuyuna ores to be made up of a hydrated form of hematite, probably goethite, limonite, some pure hematite, magnetite, quartz, kaolin and minute quantities of other minerals.

From the chemical analyses of the different ores, knowing the minerals composing each phase, we can make up the mineral composition by percent weight for each type of ore. The ferric oxide is combined into limonite or hematite according to the amount of combined water left over after the kaolin is calculated. The remaining water goes into limonite. All the FeO is combined to form magnetite and the remainder of the Fe_2O_3, after limonite and magnetite are made up, goes into hematite. The actual hydrated ferric oxide present in the ores in most abundance is probably not limonite and hematite, but goethite; nevertheless but slight error is introduced in combining all the ferric oxide into limonite and hematite and the degree of hydration is better shown.

Average Hard Ore.—Below we have the mineral composition by weight of the average hard ore:

Hematite	=	37.80 per cent.
Limonite	=	40.50 per cent.
Magnetite	=	10.00 per cent.
Quartz	=	6.89 per cent.
Kaolin	=	2.53 per cent.
Accessory minerals	=	2.28 per cent.

Note that the limonite is in larger proportion than the hematite, showing that the ore is well hydrated.

Average Soft Ore.—The average soft ore is made up as follows:

Limonite	= 29.00 per cent.
Hematite	= 45.45 per cent.
Magnetite	= 9.85 per cent.
Quartz	= .47 per cent.
Kaolin	= 14.20 per cent.
Accessory minerals	= 2.80 per cent.

Although this analysis is an average of 125 feet of drilling in three different localities in true soft ore, the amount of kaolin is higher and the amount of quartz lower, in all probability, than the true average soft ore of the Cuyuna. The other constituents of this analysis represent nearly a true average.

Note the higher proportion of hematite to limonite in the soft ore, or the lesser amount of hydration, and the constancy of magnetite in both types.

Density, Porosity and Cubic Contents of the Various Types of Ore.

The specific gravity or density of the ores and other associated rocks was determined physically from large hand specimens of the ore in question. These specimens were soaked, or boiled in water, depending on the degree of induration of the ore, for from 10 to 24 hours, in order to saturate all pore space. They were then weighed in air and under water in this saturated condition. The samples were then dried at 105° C. for some time to expel all moisture or uncombined water, then weighed in air. The density of the sample in question = weight in air (dried) divided by weight in air (dried) — weight in water (saturated). The moisture of saturation of the specimen = weight in air (saturated) divided by weight in air (saturated) — weight in air (dried). If we let M represent the moisture of saturation

as determined above and G represent the density, the pore space of the rock in question is determined as follows:

$$\text{Porosity} = \frac{M}{M + \frac{100 - M}{G}}$$

The cubic contents or run in cubic feet per ton is calculated from the moisture of saturation, pore space and density by a method developed by W. J. Mead and set forth in the Monograph on the Lake Superior Region by C. R. Van Hise and C. K. Leith.

The density of both types of hard ore of standard grade averages 4.09. The low figure is due to the hydrated character of the Cuyuna hard ore. The density of the soft ores averages 4.19 and of lean soft ore 3.73. The hard blue hematite has an average density of 4.26. The limonitic brecciated hard ore shows a density of 3.95. The pore space of both types of hard ore averages 13.13 per cent. by volume. The soft ore has an average pore space of 36 per cent., and the lean soft ore 33.3 per cent. The hard ores show quite a range in porosity varying from 9 per cent. to 20 per cent. by volume.

The run in cubic feet per ton for the various types of Cuyuna ore follows:

The hard ores of both types average 10 cubic feet per ton. The hard blue hematite varies between 9 and 10.5 cubic feet per ton. The hydrated brecciated hard ore ranges from 10 to 10.8 cubic feet per ton. The soft ores average 11.5 cubic feet per ton. The lean soft ore runs 12.6 cubic feet per ton. An average figure to use in computing tonnage for a large deposit, where various ores are represented and a tonnage estimate of each type is out of the question, would be about 11 cubic feet per ton.

THE FERRUGINOUS CHERTS.

General Description.

The ferruginous cherts of the Cuyuna district are composed of bands of iron oxide, limonite and hematite, alternating with

bands of chert. The ferruginous chert is encountered in all stages of alteration and thus shows a variety of phases. There are, however, on the Cuyuna three separate types which are far enough apart in chemical and physical characteristics to be classed separately.

The banded ferruginous cherts form one class. This type of rock includes the bulk of the ferruginous cherts and by far the largest part of the whole iron formation. This rock is composed of alternate light and dark bands, varying from less than a quarter of an inch to six inches or more in width. The light bands are relatively pure chert, the dark bands are iron ore, more or less siliceous. In the unaltered stage this rock is hard, dense and has but little pore space. As generally encountered it shows the beginning of alteration to ore, with the chert bands often somewhat softened by leaching. In much of this chert the banding is on too large a scale to show in the hand specimen.

The second type of ferruginous chert is a black, dense, massive rock showing stringers of hematite throughout the mass, the hematite being crystallized on a small scale in the form of kidney ore. This chert is highly ferruginous, averaging about 45 per cent. Fe. It has but little pore space and breaks with a conchoidal fracture. In drill cores this type is very easily confused with hard ore. It has been encountered in considerable amounts in the Rogers Brown mine.

The third type is a weathered variety composed almost entirely of granular quartz. This phase is light colored and may show light and dark banding, the dark chert bands owing their color to iron oxide staining. The iron content is however very low. Much of this chert is light yellow and is very similar to a sandstone in texture and color. It is fairly soft and crumbles easily. The amount of pore space is greater than in the other ferruginous cherts.

Chemical Composition of the Ferruginous Cherts.

Average Feruginous Chert.—The average ferruginous chert is made up as follows:

SiO_2	= 47.49 per cent.	Accessory constituents	= 2.00 per cent.
Al_2O_3	= .62 per cent.	Fe	= 33 per cent.
FeO	= 2.78 per cent.		
Fe_2O_3	= 43.71 per cent.		
H_2O+	= 3.41 per cent.		

This is an average of several analyses made from both the closely banded and the massive types. It does not, however, represent the dense, black, highly ferruginous cherts which grade into cherty ore and are higher in iron.

Mineralogical Composition of the Ferruginous Cherts.

Examination of thin sections shows the ferruginous cherts to be composed of quartz, goethite, hematite, limonite, magnetite, a little kaolin and minute quantities of other minerals.

Average Ferruginous Cherts.—The following is the mineral composition of the average banded ferruginous chert of the district, figured in the same manner as for the ores:

Quartz	= 46.66 per cent.
Limonite	= 21.20 per cent.
Hematite	= 19.51 per cent.
Magnetite	= 9.00 per cent.
Kaolin	= 1.52 per cent.
Accessory minerals	= 1.76 per cent.

Note that the percentage of magnetite is about the same in the average ferruginous chert as in the average ores.

Density, Porosity and Cubic Contents of the Ferruginous Cherts.

The average ferruginous chert of the banded type has a density averaging 3.23. The dense, black, highly ferruginous chert averages 3.69, while the weathered chert averages 2.74.

The porosity of the average banded type is 8.35 per cent. by volume and varies between 6 per cent. and 11 per cent. The black highly ferruginous chert has an average porosity of 5.8 per cent. by volume. The weathered chert shows an average pore space of 11 per cent. and runs as high as 16 per cent.

The run in cubic feet per ton of the various phases of ferruginous cherts follows: The average banded ferruginous chert runs

13.5 cubic feet per ton and ranges between 11.9 and 14.3 cubic feet. The black highly ferruginous chert averages 10.2 cubic feet per ton. The weathered chert averages 14.1 cubic feet per ton.

THE CHERTY IRON CARBONATE ROCK.

General Description.

Specimens of this, the original iron formation rock, are at present only obtainable on the Cuyuna range in drill cores. The rock shows a closely banded structure, with alternating bands of siderite and chert. It occurs in all gradations from the pure cherty iron carbonate to the slaty and amphibole magnetite phases and presents a different appearance for each phase. In its unbanded form the rock has light yellow and greenish colors and presents a mottled appearance, similar to some marbles. The rock is hard and can not be easily scratched with a knife. When banded, the banding is almost always close, the bands ranging from an eighth to a half inch or more in width, as a rule.

Most of the cherty iron carbonates of the Cuyuna have suffered recrystallization under anamorphic conditions, where the CO_2 has had no chance to escape. The siderite bands in the iron carbonate rock therefore show good crystals, the curved rhombohedral faces being apparent to the eye, on examining a core. These large siderite crystals thus give a core from this rock a characteristic appearance. Not all the cherty carbonates show this coarse crystallization. In the mottled unbanded phases the crystallization is too fine to get any play of light on the crystal faces and indeed too fine to distinguish the crystals with the naked eye. Small particles of magnetite can often be seen. The cherty iron carbonate of the Cuyuna is a hard dense rock with a negligible amount of pore space. Secondary iron carbonate associated with hematite ores high in magnetite has been found in the Pickands Mather shaft on the south range in section 8–45–29.

Chemical Composition of the Cherty Iron Carbonate.

The chemical composition of the average cherty iron carbonate of the Cuyuna district is as follows:

SiO_2	= 38.10 per cent.	Accessory constituents = 5.45 per cent.
Al_2O_3	= 5.04 per cent.	
FeO	= 23.23 per cent.	
Fe_2O_3	= 14.00 per cent.	
H_2O+	= 2.08 per cent.	
CO_2	= 12.00 per cent.	

The above represents an average sample made up from drill cores from holes in iron carbonate rock in different parts of the district. Probably alumina is too high.

Mineralogical Composition of the Cherty Iron Carbonate Rock.

The cherty iron carbonates are composed of siderite, quartz, magnetite, kaolin, hematite, limonite—the two last in minor amounts with sometimes a trace of amphibole.

The average rock of this type is made up as follows:

Siderite	= 31.50 per cent.
Quartz	= 32.16 per cent.
Magnetite	= 11.60 per cent.
Hematite	= 4.30 per cent.
Limonite	= 2.00 per cent.
Kaolin	= 12.75 per cent.
Accessory minerals	= 5.69 per cent.

Note that the amount of magnetite is as large as the magnetite content of the ferruginous cherts and the ores.

Kaolin is higher than usual on account of a rather slaty phase of the cherty iron carbonate having been included in this general average.

PAINT ROCK.

General Description.

The paint rock associated with the Cuyuna ores is similar to that encountered on the Mesabi range and needs no detailed description. It is soft, soapy in feel and deep red or red brown in color. It is composed essentially of clay, limonite and hematite, with much pore space.

Chemical Composition of the Paint Rock.

Below is an average analysis of specimens taken from the Rogers Brown mine:

SiO_2 = 42.65 per cent.
Al_2O_3 = 19.38 per cent.
Fe_2O_3 = 30.31 per cent.
H_2O— = 7.36 per cent.

Fe = 21 per cent.

The rock is fairly high in iron, as is witnessed by its deep red color, and correspondingly low in alumina. It was not analyzed for FeO; but that element is present in small quantity, since small scattered particles of magnetite can be discerned under the microscope.

Mineral Composition of the Paint Rock.

Kaolin = 49.00 per cent.
Limonite = 3.40 per cent.
Hematite = 27.41 per cent.
Quartz = 19.85 per cent.
No accessory minerals.

Density, Porosity and Cubic Contents of the Paint Rock.

The average density of the paint rock is 2.94, the porosity is 45 per cent. by volume and the run in cubic feet per ton is 17.5.

THE AMPHIBOLE MAGNETITE ROCK.

General Description.

This is typically a closely banded, fine-grained rock varying in color from dark gray to almost black, through shades of greenish gray, to a brown and light colored banded form. The banding is close, the bands varying in width from one-sixteenth inch up to one-half inch or more, with cleavage nearly parallel to the banding. The finely crystalline magnetite tends to concentrate in fine bands and is readily distinguishable by its steel blue color. The crystals are large enough to be made out with the unaided eye, or with a small hand lens. Commonly the amphibole, either grünerite or hornblende or both, can not be distinguished in the core with the unaided eye. Where it can be made out, it is light to dark green in color. Usually what is most plainly seen in a core from this rock is bands of magnetite alternating with bands of light or dark gray quartz or with brown chert bands. If the specimens be made up largely of magnetite and quartz it will be

dark gray in color. If amphibole and quartz predominate the rock will be greenish gray.

Mineral Composition of the Amphibole Magnetite.

Under the microscope we find the Cuyuna amphibole magnetite rock to be composed of magnetite, quartz, amphibole, chlorite, hematite and limonite in minor quantities, a little unanamorphosed siderite, and quite a little pyrite or pyrrhotite disseminated through the mass. Small quantities of mica may be present. The amphibole magnetites have little or no pore space.

PART III.

THE ORIGIN AND SECONDARY CONCENTRATION OF THE CUYUNA ORES.

The development of the ore deposits from the cherty iron carbonate rock took place in two stages, first the development of ferruginous cherts from the cherty iron carbonate by oxidation and hydration; second the concentration of the ore from the ferruginous chert by the leaching out of silica and the secondary introduction of iron.

THE INFLUENCE OF STRUCTURAL CONDITIONS ON THE DEVELOPMENT OF THE ORES.

As has already been pointed out the characteristic occurrence of the ore deposits is in steeply dipping beds, between impervious layers of slate or iron formation on the "hanging wall" and "foot wall" sides of the ore body, and with gradation into unaltered iron formation with depth, while other deposits are found in pitching troughs formed by an intruding dike and an impervious layer of the steeply dipping iron formation or slate.

The steeply dipping confined beds serve as channels in which the meteoric waters, circulating through the iron formation, are gathered and along which they flow.

The circulating waters entered the iron formation where the truncated lenses were exposed on the limbs of the anticlinal folds

and tended to concentrate in the natural channels thus formed. At one time the actual rock surface was exposed and the level of the ground water stood some distance below the surface, and the meteoric waters entering the exposed surface worked downward till the level of the ground water was reached. These downward circulating waters, heavily charged with oxygen, were responsible for the chemical reactions in the alteration of the iron formation.

ALTERATION OF THE CHERTY IRON CARBONATE TO FERRUGINOUS CHERT.

The cherty iron carbonate rock consists chiefly of $FeCO_3$ and SiO_2. The main chemical reaction in this alteration to ferruginous chert consists in the oxidation of the iron, or the changing of ferrous to ferric iron. The silica does not change. The reaction is:—$2FeCO_3 + nH_2O + O = Fe_2O_3 \cdot nH_2O + 2CO_2$.

The cherty iron carbonate consists essentially, as previously shown, of alternate layers of siderite and silica. The siderite changes to ferric oxides, while the silica remains mineralogically unchanged though a little is probably carried out.

The change from siderite to limonite and hematite involves a change from a light to a dense mineral. Leith has calculated that a pure siderite altering to a fine hematite will lose 49 per cent. in volume. The same siderite altering to limonite will lose 18 per cent. volume.

The decrease in volume in the change from siderite to ferric oxide causes a shrinkage of as much of the rock mass as was occupied by the siderite. Since the siderite is scattered through the mass of the cherty iron carbonate rock in bands and numerous irregular particles, this shrinkage will affect one part of the rock and not the other and so the rock as a whole will develop a little pore space.

Several different drill holes on the Cuyuna range, penetrating the iron formation parallel to the dip of the beds, show by their cores the actual gradation, as the depth increases, from ferruginous chert to cherty iron carbonate rock. Almost any deep

hole in the Deerwood formation, which starts in ore or ferruginous chert shows cherty iron carbonate at the bottom. We know, then, that cherty iron carbonate and ferruginous cherts make up a large mass of the Deerwood formation and that one grades gradually into the other.

A thin section from a core of the Cuyuna cherty iron carbonate shows the actual alteration of the iron carbonate to ferric oxide. The light ground mass of the slide, mainly iron carbonate shows alteration along fissures, and other portions exposed to weathering, to hematite. This gives us actual proof that the iron carbonate alters by weathering to ferric oxides.

The cherty iron carbonate rock of the Cuyuna district contains about 40 per cent. silica and 28 per cent. siderite by volume, in the rock. The shrinkage in volume then, due to the changing of siderite to ferric oxides, will be effective on 28 per cent. of the rock. We find that the average ferruginous chert of the Cuyuna district contains about three parts by volume of limonite to two parts hematite. The loss in volume of siderite in altering to limonite and hematite in this proportion would be about 30% of the volume of the siderite. Taking the cherty iron carbonate rock as a whole, the loss in volume in altering to ferruginous chert would be 30 per cent. of 28 per cent. = 8.4 per cent. This loss in volume is the porosity that is developed in the ferruginous cherts. We find that the actual average pore space of the ferruginous cherts of the Cuyuna is 9 per cent. of the volume of the chert, which corresponds closely to the volume loss just figured.

ALTERATION OF THE FERRUGINOUS CHERTS TO ORE.

In general the alteration of any ferruginous chert to an ore consists mainly in the removal chemically and physically of the silica from the chert and the consequent volumetric concentration of the ferric oxides in the resultant rock. This secondary concentration to ore may take place as outlined above, with or without the secondary introduction of iron.

In the Rogers Brown mine and in almost any drill hole in ore on the Cuyuna range the actual gradation from ore to ferruginous

chert can be seen. The process by which the Cuyuna ores develop from the ferruginous cherts is shown by a series of diagrams illustrating the volumetric and chemical changes observed as the ferruginous cherts grade into ore.

On the first diagram the ferruginous cherts and ores are plotted

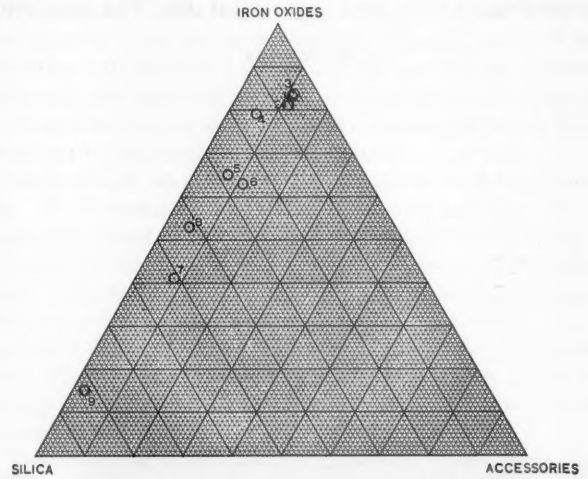


FIG. 18. Diagram showing composition of various phases of ferruginous cherts and ores in terms of silica, iron oxides and accessory constituents (alumina and H_2O+ chiefly).

as to percents by weight of the above three chief constituents. No account is taken of pore space.

Point 1 represents the analysis of hard blue ore from the Rabbit Lake section.

Point 2 = brecciated hydrated hard ore (Rabbit Lake).

Point 3 = hard blue ore (section 21–46–28).

Point 4 = soft ore (section 21–46–28).

Point 5 = lean soft ore (Rabbit Lake).

Point 6 = dense black highly ferruginous chert.

Point 7 = an average ferruginous chert.

Point 8 = an average ferruginous chert.
Point 9 = weathered highly siliceous chert.

The diagram is an equilateral triangle crossed by three sets of equally spaced lines, 100 lines to a side. Percents are measured from 0 per cent. to 100 per cent. from any side of the triangle, perpendicularly to the apex opposite that side. The apices repre-

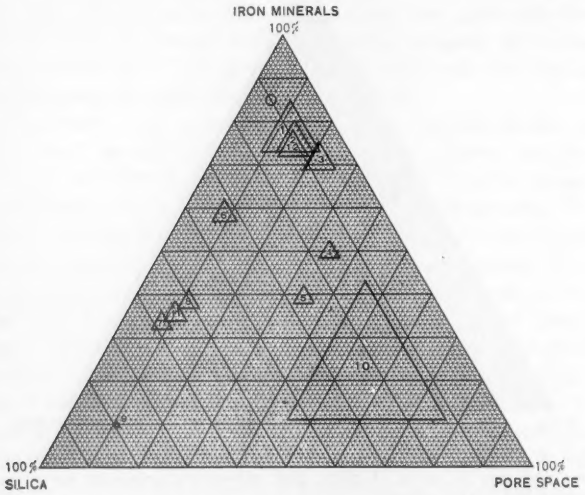


FIG. 19. Diagram representing the volume composition, in terms of iron forming minerals, silica, pore space and kaolin and other accessory minerals, of the different phases of the Deerwood iron formation.

sent 100 per cent. respectively of iron oxides, silica and accessories. Thus point 8, representing the analysis of a ferruginous chert, shows the chert to be made up of 53 per cent. iron oxides, 42 per cent. SiO_2 and 5 per cent. accessories.

The grouping of the points representing the different phases of cherts and ores shows wide variation between silica and iron oxides while the percentage of accessory constituents (alumina and H_2O+) varies but little. That is, as iron oxides increase,

silica decreases, in the change from chert to ore; while through the whole alteration the alumina and H_2O+ remain practically constant. This brings out the point that the chief chemical action, as the Cuyuna ferruginous cherts grade into ore, is the removal of silica.

The second diagram shows volume compositions in terms of iron minerals, silica and pore space for different phases of the formation. It also shows the volume changes in iron minerals, silica and pore space, from phase to phase in the alteration of a ferruginous chert to an ore and also the relations which these three bear to each other during the process of alteration.

Small triangle no. 1 represents the massive hard blue hematite. No. 2 represents the brecciated limonitic hard ore. No. 3 represents a hard ore from section 21–46–28. No. 4 shows a soft ore from 21–46–28. No. 5 shows the lean soft ore (Rabbit Lake). No. 6 shows the dense, black, highly ferruginous chert. Nos. 7 and 8 represent two banded ferruginous cherts. No. 9 represents the weathered chert. No. 10 shows the typical paint rock. No. 11 shows the average ferruginous chert, no. 12 the average hard ore, no. 13 the average soft ore and no. 14 the average cherty iron carbonate.

The method of measuring percentages on the triangular diagram here shown is the same as used on the previous diagram. There the percentages of silica, ferric oxide and accessories were measured by weight. Here iron minerals, silica and pore space are measured by volume. Thus a point O, near the top of the triangle, represents a theoretical ore composed of 85 per cent. by volume of iron minerals, 10 per cent. by volume of silica and 6 per cent. by volume of pore space. As a matter of fact, however, the sum of the volume percents of the above three main constituents in an actual analysis of any chert or ore, falls short of 100 per cent. due to the percentage of kaolin and other minor constituents. Thus the actual analysis can not be represented by a point on the triangle. However, by drawing a short line parallel to the side of the triangle representing 0 per cent. of each major constitutent at the proper perpendicular distance from

that side to represent the percentage of that constituent in the ore or chert being platted, is constructed a small equilateral triangle within the larger one which by its position on the large triangle shows the volume percentages of pore space, iron minerals and silica in the phase it represents and by its height shows the percentage by volume of kaolin and accessory minerals in that phase. Thus small triangle 8, representing a banded ferruginous chert, shows the chert to be composed of 10 per cent. pore space, 49 per cent. silica, 37 per cent. iron minerals and 4 per cent. kaolin and other accessories.

Several interesting facts bearing on the alteration of cherts to ore are brought out by the above. Consider one of the small triangles at the left representing a ferruginous chert. We see that it is high in silica and low in pore space. As silica decreases we see from the diagram that pore space increases. If the concentration to an ore takes place wholly by removal of silica and the consequent increase of pore space then the alteration of ferruginous chert to ore will be represented on the diagram by a succession of small triangles lying in a line from left to right, and at a constant distance from the bottom. That is, the amount of iron will remain constant throughout the change.

Given a ferruginous chert that is high in iron then this change could proceed as above without developing an impossible amount of pore space; but starting with a chert low in iron, as we progressed to the right we would have developed an impossible amount of pore space, by the time we had silica low enough to come within the limits of an ore. Hence the rock would slump, and pack down. This would cause a volumetric increase in the percentage of iron in the resulting rock. On the diagram the small triangle representing such an ore or rock would move upward after slumping had taken place.

Thus, starting with an average ferruginous chert, if the concentration took place wholly by removal of silica, iron remaining constant and pore space increasing as silica was leached out, we would have the alteration represented by small triangles proceeding in a horizontal line towards the right; but if the con-

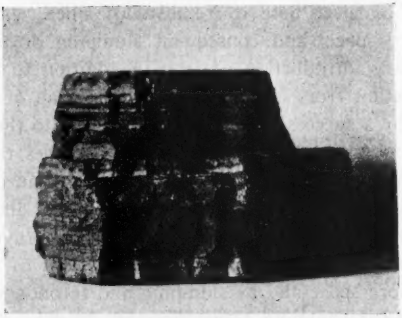


FIG. 20.

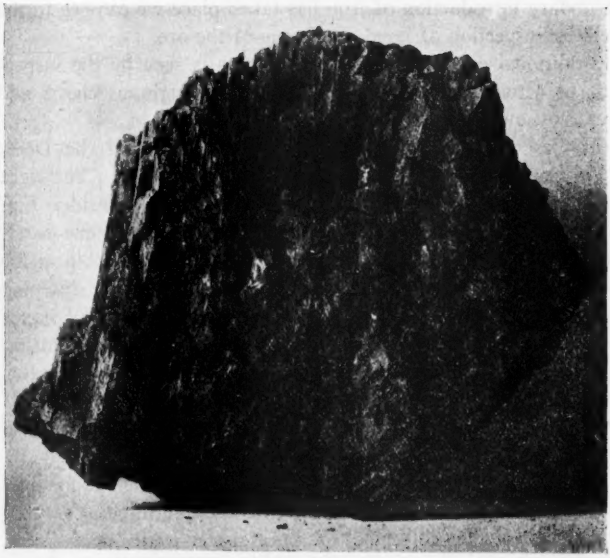


FIG. 21.

Photographs of the typical banded ferruginous chert of the Cuyuna district and the hard ore resulting from the alteration of the ferruginous chert. Note the original bedding or banding of the hematite layers in the chert, still discernible in the ore.

centration took place both by removal of silica, with development of pore space, and consequent slumping or packing, or with secondary introduction of iron in addition to these, then the concentration from a ferruginous chert to an ore would be represented by a succession of triangles moving to the right and upward. Looking at the series of small triangles representing the alteration stages from a ferruginous chert to an ore, we see that they move to the right and upward. The diagram thus shows that the secondary concentration of the Cuyuna ferruginous cherts to ores took place by the removal of silica with increase of pore space and by slumping and secondary introduction of iron; the slumping being brought about by the production of too large a pore space through removal of silica. That secondary introduction of iron has taken place we can see in the field by inspection of hand specimens of the ore.

Additional evidence of the above steps is seen by the inspection of actual specimens of the Cuyuna ferruginous cherts and ores, as shown on plate.

Fig. 20 is a typical banded ferruginous chert of the Deerwood iron formation showing even parallel banding. The light bands are chert, the dark bands are ore. Now consider Fig. 21, a typical specimen of the hard ore showing the same banding as in the ferruginous chert, which are still traceable in the ore after the layers of chert have been leached out and slumping has taken place resulting in an ore composed entirely of bands of hematite. Typical brecciated hard ore, with close fracturing or brecciation has resulted from the slumping of the rock after the removal of the silica layers by leaching. Thus inspection of actual ores in the field bears out the facts brought out by the triangle diagram.

The diagrams on Fig. 24 show these changes better than is possible by the triangular diagrams. The average mineral compositions by volume, corrected for pore space, were obtained for the above three stages from the chemical analyses of the Cuyuna iron carbonates, ferruginous cherts and ores. The amount of porosity shown for each stage of alteration is the average of

the actual porosity determinations on hand specimens representing each of the above stages of alteration.

The actual amount of ferric oxides and magnetite remains the same in the development of the average ore from the average ferruginous chert, while the silica has been almost all removed. The accessory minerals show little change in volume. The pore space developed by the removal of the silica has become so great that slumping has resulted.

THE DEVELOPMENT OF MAGNETITE IN THE CHERTY IRON CARBONATE BEFORE ITS ALTERATION TO ORE.

In reviewing the development of the Cuyuna ores we see that the changes which took place are similar to those of the Mar-

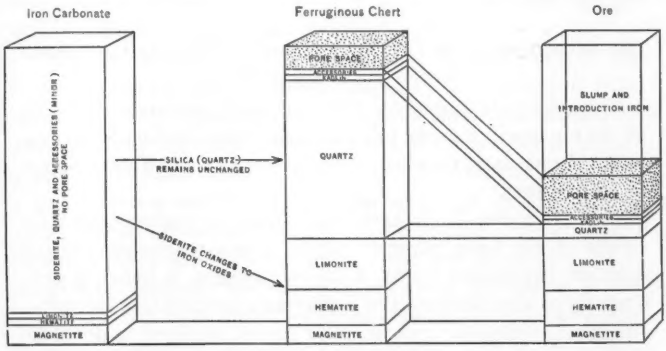


FIG. 22. Columnar diagrams showing the volume changes in the development of the hard and soft ores from the cherty iron carbonate rock, through the ferruginous chert.

quette, Menominee and Penokee Gogebic ranges, where part or the whole of the original iron formation was the same as that of the Cuyuna district. There is one point however where the cycle of development differs markedly. On the Cuyuna, magnetite was developed in the cherty iron carbonate before it began to alter to ore. This is true not only for the anamorphosed por-

tions of the iron formation, the amphibole magnetite rock, but also to a lesser extent for the whole of the iron formation.

Microscopic examination of any of the cherty iron carbonate rock of the Cuyuna district will show numerous well-developed small crystals of magnetite scattered through the mass. Similarly all the phases of ferruginous cherts and ores show well-crystallized magnetite scattered through the mass of the rock.

The columnar diagrams illustrating the volume changes in the development of the average ore, show that the per cent. by volume of magnetite is about the same for all these stages. This shows that the magnetite present was developed before the alteration to ore began; also that little or no additional magnetite was developed during the process of alteration or after the ore had formed.

THE DEVELOPMENT OF THE AMPHIBOLE MAGNETITES ASSOCIATED WITH THE ORE DEPOSITS.

The amphibole magnetites which are so closely associated with all the ore deposits on the Cuyuna range were developed previous to the alteration of the cherty iron carbonate rock to ferruginous cherts and ores.

Van Hise and Leith have noted that, throughout the iron ranges of the Lake Superior region, where anamorphic forces work on ferruginous cherts, a banded jaspalite is found, a rock made up of alternate bands of bright red chert and blue hematite. Amphibole magnetite rock is never found produced under such metamorphic conditions.

Weathering of the iron formation to ferruginous chert and ore has taken place on the upper part of the steeply dipping lens of iron formation. This weathering has proceeded downward until a zone of impervious amphibole magnetite was reached. If this amphibole magnetite had not been developed before weathering commenced the alteration would have proceeded till the dike itself was reached and we would have had ore and ferruginous chert in direct contact with the dike. Had the anamorphic forces, capable of producing such rocks as amphibole magne-

tites, been active after this bed of iron formation had altered to ferruginous cherts and ore, then we would have a zone of hard ore jasper separating the weathered portion of the formation from the dike instead of a zone of amphibole magnetite rock. No hard ore jasper has been found near any intrusive into the iron formation on the Cuyuna range, neither has ore been found in direct contact with a dike, but a zone of amphibole magnetite rock separates the ore or ferruginous chert from the dike itself. Thus the relations of the amphibole magnetite rock of the Cuyuna range to the associated ferruginous cherts, ores, cherty iron carbonate rock and the intruding igneous masses, show that the amphibole magnetite rock was developed in the cherty iron carbonate rock before the latter had commenced to alter by weathering; that is, before the iron formation was exposed by the planing off of the tops of the anticlinal folds.

This rock is similar to the amphibole magnetite rock of the Penokee Gogebic and Marquette ranges. The anamorphic conditions which produce such a rock from a cherty iron carbonate rock are fully discussed by Van Hise and Leith in their Monograph on the Lake Superior Region, so it is sufficient to say that such conditions are due to the intrusion of hot igneous masses into the iron formation rock or to acute folding, producing differential movement between beds of the iron formation. The amphibole magnetite will be developed along the contact of the intrusives with the intruded iron formation or along planes where differential slipping has taken place between beds in the folded iron formation or between an iron formation bed and the bounding slate.

We do not know the relative importance of the parts played in the development of the amphibole magnetite rock by the intrusives and by the acute folding of the iron formation. It would seem that most of the amphibole magnetite was developed by the intrusion of the igneous dikes, on account of the close association of the amphibole magnetite with these dikes.

SEQUENCE OF ORE CONCENTRATION ON THE CUYUNA RANGE.

The cherty iron carbonate formation was deposited in lens-shaped beds through the great St. Louis slate formation in Upper Huronian time. In Keweenawan time and possibly in late Upper Huronian, the St. Louis slates and included lenses of the Deerwood formation, in the Cuyuna area, were intruded by numerous masses of igneous rock. The intrusion of these many masses of igneous rock caused the Upper Huronian sediments of this locality to be acutely folded. The intrusive masses and the consequent sharp folding caused part of the iron carbonate formation to be anamorphosed to amphibole magnetite rock.

In the long erosion period preceding and during late Keweenawan time, the tops of the anticlinal folds in the St. Louis slate were planed off, thus exposing to the weathering agents the tops of the truncated beds of iron formation. These beds at this time were composed of cherty iron carbonate and amphibole magnetite. The amphibole magnetite rock, being hard and resistant, suffered little alteration. The surface waters, percolating downward through the steeply dipping beds of iron formation, altered the cherty iron carbonate rock with which they came in contact to ferruginous chert and ore.

RELATION OF SCIENTIFIC TO PRACTICAL WORK IN STATE SURVEYS.[1]

EDWARD B. MATHEWS.

Few questions concerning the administration of state surveys are more important than that of the determining the ratio between the time and money devoted to scientific work and to investigations with an immediate "practical" result. The subject has frequently been the topic of discussion and more frequently the occasion of serious consideration on the part of state geologists, and yet, so far as I am aware, it has never been answered to the satisfaction of all. Moreover, judging from its perennial reappearance, its vigorous vitality, and its sensitiveness to environment, it never will be. Approximations to the solution of the problem, however, may be gained by a consideration of the general factors involved and their relative importance to specific instances.

The *first* of the factors to which attention may be called is the patent fact that appropriations for official surveys are made with the expectation that practical ends will be served by the discovery or delimination of workable natural resources. (These practical ends may also in some instances include map-making, road-construction, and a score of similar subjects.)

In the mind of the average legislator who votes for an appropriation for geological work there is little or no knowledge of geology or of the results which the promoters of the organization expect to realize. On the other hand, there is a more or less well defined belief that in some mysterious way a geologist possesses powers by which, as he walks over the surface of the ground, he can tell what lies beneath. The appropriation for which the vote is cast is believed to be the means by which the geologist can be made to use his occult powers to disclose the

[1] Prepared for the Association of State Geologists and published in accordance with vote taken at the Pittsburg meeting, December, 1910.

hidden riches for the benefit of the state. When moneys thus appropriated are applied to the elucidation of scientific problems unconnected with the usable mineral deposits, the legislator and the public generally believe that the state has been dishonestly mulcted and the work which we know to be of value to the state falls into disrepute and the good which should be accomplished is put in jeopardy. This feeling must be recognized and the work must be planned with reference to it, while the geologist must possess himself in patience doing what he can towards the accomplishment of scientific results as a secondary issue until his clientele has been educated to a correct appreciation of the relative merits of the different types of work for the betterment of the state which must ultimately be performed by a geological survey.

A *second* factor in the problem is another equally accepted fact, viz., that the public generally and the scientific or professional element in particular expect the work to be done accurately. The term "accurate," however, covers different concepts, qualitatively and quantitatively, in the minds of the public laity and of the trained specialist. The former thinks of accuracy of detail where error may produce financial loss, but is satisfied to call "accurate" a general treatment drawn with a firm, broad, impressionistic stroke even if the details are wrong or lacking. The professional attitude, however, stimulated by the worship of thoroughness and allegiance to the truth for truth's sake, conceives that accuracy demands the correctness of drawing and the wealth of detail characteristic of an architectural working plan.

Between these extremes stand the more enlightened among the laity and the humane scientific worker who bears in mind the next element involved in the question.

The *third* factor to be considered in a solution of the problem is the fact that moneys expended in the prosecution of a geological survey are raised by taxation (direct or indirect), and that taxation in the end often works hardship on that portion of the body politic whose income and expenses are in delicate or unstable equilibrium. For humane as well as diplomatic reasons

the funds appropriated should be husbanded carefully and applied where they will produce the greatest good to the greatest number. These conditions should prohibit such applications of funds as have for their stimulus the personal scientific ambition of the geologist and for their end a gratification of personal pride in the solution of such questions as the detailed limit of geological units which do not affect either the commercial development or the solution of the scientific questions involved. It is probably true that geologists have more than once spent time, energy, and money in endeavoring to trace the limits of small dikes in a continuous country rock when their distribution is below the scale of representation and without influence or meaning in the problems of the area. Many of the more refined questions of stratigraphic geology involve the same factor. The detailed mapping of minute lithologic or paleontologic units, often below the limits of the scale of publication increase the costs and absorb the time of the official geologist far beyond the resulting benefit accruing to the state. There is in scientific research, as in everything else, the limit set by the economic law known as the Law of Diminishing Returns. To pass this limit is to decrease the efficiency of the organization and to endanger its very existence before its legitimate beneficial work is completed.

Besides these three factors in which the public and the specialist are both interested and, in a way, competent to express an opinion of value, there is the more specific group of questions which can only be solved by the specialist. These involve the major lines of the plan adopted and the ultimate forms of publication issued by the organization. The investigation of a given commonwealth may proceed by exhaustive studies and slow areal progress or by areal studies of successively increased refinement. The first method leads to relatively more scientific work in terms of practical results and ultimate cost, the latter to an appearance of greater results with less expenditure of time and money at first but with greater ultimate expense to the state.

Again, the work may be conducted by an investigation of specific topics as has recently been suggested by Professor Irving, or

by areas following the progress of topographic mapping. The decision reached by the administrator in these two questions will greatly influence his position regarding the relative apportionment of funds for practical, that is immediate, and scientific or ultimate, results. To the systematist or the specialized investigator in science who is perchance untrammeled by the demands of expediency it would appear better to solve with refinement the stratigraphic elements of his column or the genetic interpretation of his deposits rather than promulgate with approximate accuracy the information regarding a given area. On the whole, I think it can be safely asserted, that it is generally cheaper to conduct any piece of investigation to complete solution at once than to go over the same problem several times with increasing refinement. That is, it is cheaper in the long run to approach questions from the scientific rather than the practical standpoint. On the other hand, it appears equally certain that the American spirit tends to demand early reports of approximate accuracy rather than definitive discussions of the question of origin, distribution, or geological sequence encountered. Phrased in another way, the spirit of the people to whom we must look for support calls for reports of progress rather than monographic studies, for reports of ephemeral interest rather than for such as are of greater ultimate value. The attitude of the specialist tends toward well rounded, complete discussions regardless of the time of their appearance.

The foregoing statements indicating that the geological surveys are on the one hand supported by the people for immediate practical ends at a minimum cost, and on the other conducted by specialists, who from their wider knowledge and trained viewpoint believe it ultimately cheaper and better to make haste slowly, summarize the situation. It is a condition for adjustment of greater or less complexity which must vary in each commonwealth with the temper of the geologist and the training and needs of the people. There can be no single solution applicable to all conditions. It is, however, possible to idealize somewhat and arrive at answers suitable for varying conditions.

In the ideal state a geological survey should have its work so outlined that it would ultimately furnish to its constituency—

PRESS BULLETINS of ephemeral value, giving accounts of new discoveries, progress of the work, cautions against wildcat mining propositions, etc.

ECONOMIC REPORTS discussing definitively the deposits with respect to their origin, geological occurrence, areal extent and intimate peculiarities.

SUMMARY REPORTS on the natural resources of the state arranged for educational purposes, including both general systematic statements and more extensive monographic studies of a popular character.

SYSTEMATIC REPORTS containing the exact discussions of the scientific problems presented in the regions surveyed and the reasons for the positions assumed in the special economic and general educational reports.

COUNTY REPORTS phrased in easily comprehensible language with a wealth of local illustration to stimulate interest in the natural features and to satisfy the local needs by more complete treatment than would be warranted in a state-wide presentation.

The relative importance of these different types of work for a given state and the maturity of the organization prosecuting the work are contributary factors in the solution of the problem of the ratio to be maintained between "practical" and "scientific" work in a given instance.

To make the question more specific we may consider individual states without any implication that advice is intended for the illustrations chosen. In the case of large, geologically unknown states like New Mexico or Oklahoma—where the population is still relatively sparse and the interests those of pioneers developing little-known and only recently recognized mineral wealth—emphasis should be placed on the production of press bulletins and economic reports with only enough strictly scientific work to insure the probable accuracy of the published results. Such states need this type of information for their internal development and for the stimulation of immigration. The temper of the pioneer

population, the scattered distribution of its people, the low taxable basis, and the relatively large areas of unoccupied territory are not ready to support the preparation and publication of systematic or county reports. In such states the ratio between practical and scientific might well be 80 per cent. to 20 per cent.

In other states, like Iowa or Kansas—where the agricultural interests far outweigh the mineral production, where the territory is relatively well occupied, and where the wealth and intelligence is sufficient to maintain and appreciate the results of scientific work without any immediate application to utilitarian ends—relatively more time and energy can be devoted to the preparation of county and systematic reports along with those dealing with the relatively less important mineral deposits. The ratio here might well be 50 per cent. to 50 per cent.

In the older and more thickly settled states of the East, like Connecticut and Maryland—where the mineral industries, though important, are less conspicuous than the manufacturing and allied industries, and where the educational and residential features are more pronounced—along with the proper development of the mineral industries should go the preparation and publication of county, systematic and educational reports commensurate with the educational and financial development of their people. The ratio here might well be 40 per cent. to 60 per cent.

Finally in a few states, like New York and New Jersey, where organizations have been in existence continuously for a generation or two—where the various mineral industries have already been covered and much of the territory pretty thoroughly surveyed, where the taxable basis is great and the general education of the substantial people high—the chief emphasis should be laid upon revision or revamping of earlier reports upon the industries, the preparation and publication of systematic and educational reports, and the solution of purely scientific problems. Here the ratio of practical to scientific might well be 25 per cent. to 75 per cent.

To conclude this presentation of the question, it is my opinion that:

The moneys appropriated should be spent primarily for the objects which will best benefit the people, both immediately and ultimately.

The aim of the geologist should be to supply the needs a little in advance of the actual demands of the people, but not too advanced to be appreciated by them.

Since the peoples differ in their needs in the different states, and the areas within political boundaries present different problems, the ratio between practical and scientific work must vary with the development of the people, the body politic, and the problems presented.

That while geological surveys are maintained for the sake of the state and not for the sake of advancing geologists or geological science the geologist must, in part, occupy the position of prophet or teacher, and lead the people into a continuously increasing appreciation of the higher and broader scientific aspects presented by the natural features of their own environment and their duty to assist in the advancement of knowledge.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

SPECIAL PROBLEMS AND THEIR STUDY IN ECONOMIC GEOLOGY.

DISCUSSION OF EDITORIAL BY J. D. IRVING.

Sir: Your suggestions in regard to topical studies in economic geology I regard as wholesome and timely. It is always well to have clearly enunciated fundamental principles of action as chalk-lines along which we may try to hew. Since portions of your editorial dealt especially with the work of the Federal Survey it may be apropos to point out that this organization has in recent years broadened its activities along the very lines which you mention. It is perhaps trite to say that like most other active organizations the Geological Survey cannot accomplish all that its officers would like to see accomplished. The important thing is that its officers should be awake to the needs of the science and ready to take advantage of every added opportunity to meet those needs.

About 1906 added appropriations gave opportunity to enlarge the scope of the statistical work of the survey. As is well known this work was concerned mainly with the collection of statistics of mineral production and had been largely performed by a clerical force, although a few geologists also devoted some of their time to it. The results were not satisfactory even from the statistical standpoint, because of the difficulty of properly classi-

fying certain materials marketed under misleading trade names and because the personal touch with the producer was lacking.

In 1906 a large share of the work of preparing annual reports on the production of various minerals was assigned to Survey geologists. The statistical bugaboo was not at first welcomed by them with open arms. It was "first endured, then pitied, then embraced," for the geologist finally discovered that in many instances it offered him an excellent opportunity for topical geologic studies. In the course of a few years he was given an opportunity of visiting all or at least many of the leading localities in the country where a certain kind of mineral was being exploited. He could correlate, correct and amplify the scattered observations of others. He could study each deposit in the light of his experience with others, and the problems of their genesis and occurrence began to assume definite form in his mind and to yield before his attack.

The statistical part of the work is still done largely by the clerical force, but is overseen and corrected by the geologist who is personally familiar with the men and methods in the industry.

Even in the short time in which this plan has been in operation its results have been excellent. The purely scientific returns have not always been published in the "Reports on Mineral Resources" but have found their way into print through the scientific journals or elsewhere. Thus far the most definite scientific results have been obtained in the case of mineral resources of relatively minor economic importance, largely because the deposits were not too numerous to be studied by one geologist in the course of a few years. As examples might be mentioned the contributions of Mr. Frank L. Hess to the geology of the rarer metals, the work of E. C. Harder on the geology of iron and manganese, of D. B. Sterrett on the geology of mica and precious stones. Others equally noteworthy might be cited if space permitted. It is obvious that with more time and more money results equal in value to those obtained in these minor resources may be obtained in the case of the more important mineral products.

The mineral resource work of the Geological Survey then, in the writer's opinion, furnishes an opportunity for such topical studies in economic geology as you suggest. It is now doing much and it may do more.

EDSON S. BASTIN.

NOTES ON GOLDFIELD GEOLOGY.

DISCUSSION OF PAPER BY F. L. RANSOME.

Sir:—In reading F. L. Ransome's article on the "Geology of Goldfield" in Vol. V. No. 5, ECONOMIC GEOLOGY, a condensation of U. S. G. S. Professional paper No. 66, I was considerably in-

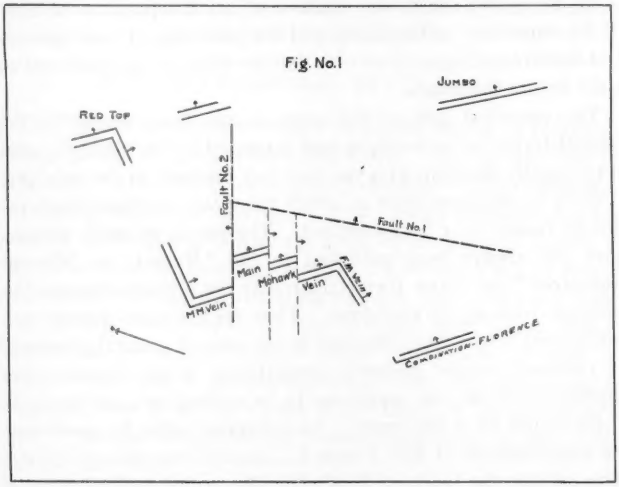


FIG. 23. Showing in part actual outcrop and in part ideal outcrop, projected to surface of these veins.

terested in his explanation of the so-called curving hanging-wall of the Mohawk vein as illustrated on the 350-foot level of the Mohawk Mine and his discussion of the difficulties attendant in the way of identifying faults in the district. I was quite for-

tunate in being able to follow closely the early development of the Goldfield mines while acting as consulting engineer for the controlling owners of the Consolidated group, and I cannot say that I agree fully with Mr. Ransome's conclusions, especially with his idea of a series of fissures, each one serving as a hanging-wall for a distance and then passing either into ledge or country rock.

I will admit that there is a multitude of minor fissures as yet untraced or identified, but a close examination of the district—

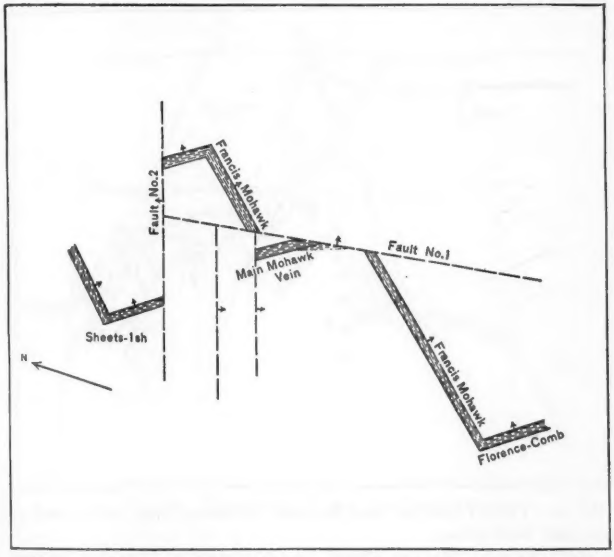


FIG. 24. Ideal plan of conditions on 350-foot level of the Mohawk.

more especially of the producing zone—discloses two separate and distinct series of breakage lines nearly at right angles to each other and both productive of ore of the same characteristics. Judging from this fact and from the fact that the ore-bodies continue around the angles where the two series of breaks meet, it would seem that they were nearly of the same age, or at least that they were both open during the time of ore deposition.

One series strikes northwest and southeast and the other northeast and southwest. In the first series, we have the Red Top and Jumbo veins, the main Mohawk vein, as disclosed in the Sheets-Ish Lease workings and the Hayes and Monnette Lease workings, the Combination-Florence vein and a part of the January vein.

In the second series, we have a part of the vein disclosed in the Sheets-Ish Lease workings, the vein disclosed in the Frances-

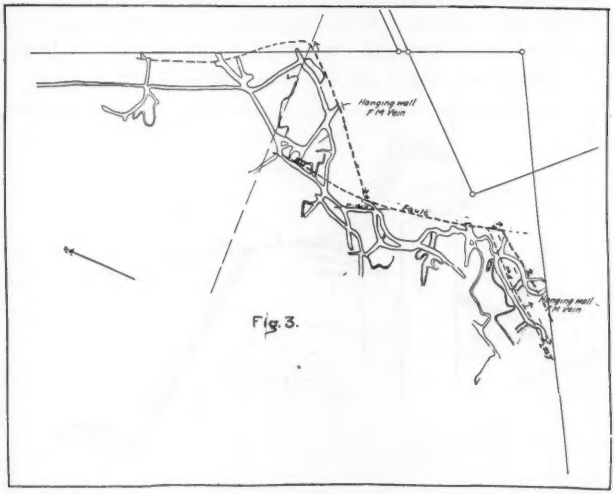


FIG. 25. Plan of 350-foot level Mohawk, indicating what part is wall and what part fault plane.

Mohawk Lease workings, the Combination Fraction, and in a part of the Company workings on the Mohawk claim and finally a part of the January vein.

Fig. 23 shows in part the actual outcrop and in part the ideal outcrop, as projected through to surface of these veins. In addition, the apices of two of the more important faults are indicated (not to scale).

The various underground workings of the properties indicate that subsequent to the deposition of the ore there was considerable faulting all over the ore-bearing district. A large number of these faults have been traced out and identified and it is found that the larger and important ones fall, like the veins, into two series, one striking northerly and southerly, and the other easterly and westerly and crossing nearly at right angles. These faults are quite easily followed and identified when passing through the

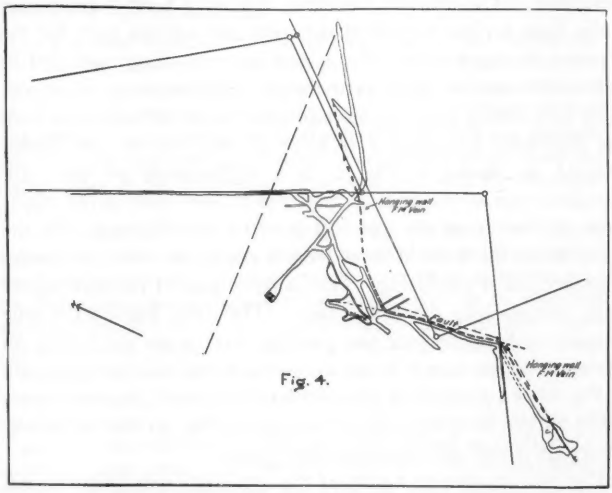


FIG. 26. Plan of part of 450-foot level Mohawk.

highly silicified portion of the zone, but on passing into the country rock the process is much more difficult.

Referring now to (Fig. 50 of Ransome's article) a plan of a part of the 350-foot level of the Mohawk, on which is indicated the so-called hanging wall of the Mohawk vein, we find it composed of a part of the hanging wall of the Frances Mohawk vein, a part of the hanging wall of the main Mohawk vein, a part of the fault plane which is shown as apexing in Fig. 1, and the hanging-wall of the Frances-Mohawk vein across the fault.

The main Mohawk vein is shown in Fig. 23 as broken somewhat by minor faults. The throw or displacement is not large in any of the cases, but the distortions give an apparent general northeast and southwest strike to the ore zone. The real strike of the veins as shown by the various segments is, however, northwest and southeast, and the general dip about 34°. The strike of the no. 1 fault varies but 15° from the strike of the vein and its dip is 40° to 45°. The strike of the Frances Mohawk vein is northeast and southwest; therefore, this no. 1 fault is practically a dip fault for the main Mohawk vein and a strike fault for the Frances Mohawk vein. The lateral throw is about 200 feet to the north and the downward throw undetermined. It is possible that, taking into consideration the main east and west fault the northeast and southwest piece of the vein in the Wedge ground, as shown in Fig. 2, is a continuation of the main Mohawk vein across fault I. Fig. 2 is an ideal plan of the conditions as shown on the 350-foot level of the Mohawk. At the point where the main Mohawk vein is cut by the fault, the conditions are rather confusing. The hanging-wall of the vein apparently merges into the fault plane. The drift follows the true hanging-wall to the junction, and the fault plane continuing on has every appearance of being a continuance of this hanging wall.

Fig. 25 is a plan of the 350-foot level Mohawk, showing the so-called curved hanging-wall of Ransome's Fig. 50, but indicating what part is wall and what part fault plane.

Fig. 26 is a plan of a part of the 450-foot level Mohawk and Combination Fraction showing the Frances-Mohawk vein on the west side of fault no. 1, the throw of 200 feet by the fault and the vein continuing on the east side of the fault. On this level, the main Mohawk vein does not show on the west side of the fault, having been cut off entirely just below the 350-foot level.

A plan of the 250-foot level Mohawk shows the same conditions as to the fault and throw as the lower levels, although somewhat more complicated by the minor faults mentioned above.

H. C. CUTLER, E.M.

REVIEW

The Geology of the Pilgrims Rest Gold Mining District. By A. L. HALL, Transvaal Mines Department, Geological Survey, Memoir No. 5, Pretoria, 1910. Pp. 158, plates 33.

With a present output of gold amounting to about two million dollars a year, the Pilgrims Rest District, sometimes incorrectly referred to as the Lydenburg Goldfields, forms, after the Rand, the most important goldfield of the Transvaal. Mining began in 1872 with alluvial diggings which produced some two and one half million dollars, but has gradually passed into the exploitation of quartz veins which occur along the bedding planes of the sedimentary series, and now yield far more gold than the placers.

The topography of the area is characterized by broad valleys bordered by escarpments and dip slopes with here and there mountain masses rising from the uplands. These features are the result of erosion on a great and diverse gently dipping sedimentary series cut by dikes and enclosing thick intrusive sills. The area mapped comprises 2,600 square miles and, save in the northeast corner and along the east border where older granites and associated schists outcrop, is formed almost entirely of rocks belonging to the Transvaal System, of which the entire succession is represented. In general the beds are but slightly faulted and dip gently to the southwest. The Transvaal System of rocks is subdivided into three parts. The lowest or Black Reef Series is composed of 60 to 2,500 feet of sandstones, quartzites and sandy shales; the intermediate member or Dolomite Series is 1,000 to 3,000 feet thick, being made up of dolomitic limestone and chert with thin bands of shale; and the upper and principal division known as the Pretoria Series, which is 12,600 feet thick, consists of three shale and three quartzite members, together with contemporaneous and intrusive igneous rocks.

Part III. of the memoir deals with the economic geology of the district and describes at least fourteen separate interbedded gold-bearing quartz reefs variously distributed from the middle of the Pretoria Series down to the base of the Black Reef Series, and in addition some five cross veins which cut the older rocks at various horizons. The former have been the chief source of revenue and the better ones of them occur in the dolomitic division of the Transvaal System. Although the inter-

mediate zones are mineralized in places yet the reefs represent remarkably definite horizons and some of them can be traced for miles along the strike of the formations. Within the Dolomite Series the mineralized horizons outcrop in a belt of country from seven to fourteen miles wide and at least forty-five miles long, as defined by the area mapped.

The reef *par excellence* of the district, but similar to the others in general characteristics, is known as the Theta Reef and occurs in the upper part of the Dolomite Series. It is from 8 to 24 inches thick and is inclosed in dolomite with which it agrees in strike and dip. The gangue material is a dirty white opaque quartz intricately honeycombed due to the leaching of iron pyrites. Unaltered ore has only been reached locally but in such places contains as high as 63 per cent. of pyrite and rarely a little chalcopyrite. The gold, which occurs in particles of microscopic size, affords an average return of from 9 to 13 dollars per ton of ore.

The flat attitude of the deposits and their remarkable persistence over wide areas leads the writer to the conclusion that the reefs are replacements, perhaps in places genetically related to the intrusion of the diorite but more frequently presenting no indications of magmatic influences.

The report is well illustrated by diagrams and plates and accompanied by an excellent map of the areal geology although to one accustomed to a contour base the use of shading for topographic features is very lacking in definiteness. The paper is clearly written and well arranged but lacks detailed microscopic descriptions of the igneous rocks and a satisfactory account of the metamorphism caused by them.

JOSEPH B. UMPLEBY.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN, J. A. ALLAN AND S. J. SCHOFIELD.

METALLIFEROUS DEPOSITS.

ANTIMONY.

Die Antimonerzlagerstätten der Umgegend von Schleiz und Greiz in reuszischen Vogtlande. By HESZ VON WICHDORFF. Zeitschrift für praktische Geologie. Heft 7, Juli, 1910. S.

COPPER.

Copper Creek Basin, Arizona. By E. HIGGINS. Eng. & Min. Jour. Feb. 4, 1911.

The ore bodies are found mainly in altered diorite, carrying pyrite bornite and cholcopyrite. Native copper occurs in sheets along shear zones. Oxides and carbonates occur at the surface. S.

Bisbee—A Geological Sketch. By W. L. TOVOTE. Min. & Sci. Press. Vol. 102, No. 5, 1911, pp. 203–208.

Outlines the previous results obtained and describes the present mining district, and several of the ore deposits in some detail. Figures show the occurrence of the ore bodies. A.

Bemerkungen über das Kupfererzvorkommen zu Stadtberge in Westfalen. By A. BERGEAT. Zeitschrift für praktische Geologie. Heft 10, Oktober, 1910.

Ein Beispiel der "Zeolith-Kupferformation" im Andesitmassiv Ostserbiens. By M. LAZAREVIC. Zeit. für prakt. Geol. Jg. XVIII., H. 2, pp. 81–82.

The Occurrence of Copper in Shasta County, California. By L. C. GRATON. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 71–111.

A preliminary report giving topography, geology, structure and metamorphism; general features, character, alteration, and genesis of the ores. The ores are believed to have come from a magmatic source and to be closely associated with alaskite. L.

The Copper Deposits of South Mountain in Southern Pennsylvania. By G. W. STOSE. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 122–131.

Summarizes the general geology, describes the ore deposits (of very doubtful value) and discusses the origin of the ore (concentration as native copper during deep-seated alteration of basalt). L.

Geology of the Copper Deposits near Montpelier, Bear Lake County, Idaho. By H. S. GALE. Bull. U. S. Geol. Survey. No. 430, pp. 112–121.

Describes the several formations, the occurrence of the copper (chalcocite and covellite in part oxidized to carbonates in "red beds"), developments and prospecting. The deposits have a possible commercial value under certain favorable conditions. L.

IRON.

Ueber Kontaktmetamorphe Eisen-Mangan-Lagerstätten im Aranyosflusse, Siebenbürgen. By W. SCHÖPPE. Zeitschrift für praktische Geologie. Heft 9, Sept., 1910. S.

Die Eisenerze des Hüggels bei Osnabrück. By E. HAARMANN. Zeit. f. prakt. Geol. Jg. XVII., 1909, H. 8, pp. 343–353.

Ueber Rödsand-Titaneisenlagerstätten in Norwegen. By J. H. L. VOGT. Zeit. f. prakt. Geol. Jg. XVIII., 1910, H. 2, pp. 59–67.

The Occurrence of Iron Ore near Haines (Southeastern Alaska). By A. KNOPF. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 144–146.

Gives geologic features and describes occurrence of the ore, magnetite, disseminated in basic rock allied to gabbro, of too low grade to be of present commercial value. Prospecting by magnetic surveys is advised. L.

GOLD.

The Gold-Fields of French Guiana, and the New Method of Dredging. By A. F. J. BORDEAUX. Bi-Mo. Bull. Amer. Inst. Min. Engineers. No. 47, 1910, pp. 889–915.

Summarizes history, statistics, and geology; describes the gold-bearing gravels, the methods and conditions of dredging in the rivers, and the quartz ledges. L.

Geology and Ore Deposits of Republic Mining District (Washington). By J. B. UMPLEBY. Washington Geol. Survey. Bull. No. 1, 1910. Pp. 65, with 13 plates and 5 figures. (Reviewed in Jour. Geology, XIX., 1911, p. 93.)

Gives general and economic geology. The gold deposits, in some respects unique, contain a great amount of selenium and are therefore correlated with those of Tonopah and Goldfield, and are thought to be genetically related to an intrusion of latite porphyry. L.

The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold Deposits. By W. H. EMMONS. Jour. Geology. Vol. XIX., No. 1, 1911, pp. 15–46.

A condensed duplicate of a paper previously listed (Bull. 46, A. I. M. E., pp. 768–837, Oct., 1910). L.

Geology and Mineral Resources of the Solomon and Casadepaga Quadrangles, Seward Peninsula, Alaska. By P. S. SMITH. U. S. Geol. Surv. Bull. 433, 1910. Pp. 234, with 16 plates and 26 figures.

Describes topography, general and economic geology. 12 pages are devoted to lode deposits, 67 to placer deposits, and 5 to water resources. L.

Sketch of the Geology of the Northeastern Part of the Fairbanks Quadrangle. By L. M. PRINDLE. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 203–209. L.

Auriferous Quartz Veins in the Fairbanks District. By L. M. PRINDLE. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 210–229.

Gives geographic and geologic sketch, describes the character of the veins, the several localities, and methods of prospecting. The values were introduced in the closing stages of vein formation. Though no profitable mines have yet been discovered, some veins merit thorough prospecting. L.

Placer Mining in the Yukon-Tanana Region. By C. E. ELLSWORTH. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 230–245.

Describes conditions and production in the Fairbanks, Circle, Rampart, Hot Springs, Forty Mile, Eagle, and Salchaket-Tenderfoot Districts. L.

Gold Deposits of Japan. Abstracted from Bureau of Mines, Dept. Agri. and Commerce of Japan. Min. & Sci. Press. Vol. 101, No. 26, 1910, p. 842.

The gold occurs chiefly in the native state, sometimes associated with pyrite, chalcopyrite, arsenopyrite, pyrrhotite, and stibnite. The mode of occurrence of the gold ores is classed as follows: (1) Fissure-filling or veins, (2) impregnations, (3) metasomatic deposits, (4) contact-metamorphic deposits, (5) mechanical detrital deposits. Most of the ore occurs in the first class. Veins occur in Archean and Paleozoic sediments, but the best deposits are in Tertiary rocks. A.

Origin of the Placer Gold of Guiana. By L. FRASER. Min. & Sci. Press. Vol. 101, No. 22, 1910, p. 703. (Synopsis of Chapt. XXV., "Geology of the Goldfields of British Guiana," by J. B. HARRISON, 1908.)

Briefly summarizes many of the explanations given for the origin of the placer gold. Harrison believes that the gold in the auriferous

quartz veins came from minute particles of gold disseminated through the basic rocks. The occurrences of gold are "accompanied by the effect of dynamo-metamorphic forces and are governed by dikes of basic rocks, either gabbros, epidiorites, hornblende schists, or the unaltered diabase." A.

Mining in Seward Peninsula. By F. F. HENSHAW. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 353–371.

A report of conditions in 1909, a year of general depression in the region. L.

The Koyukuk-Chandalar Gold Region. By A. G. MADDREN. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 284–315.

Briefly describes relief and drainage, climate and vegetation, settlements, transportation and trails, costs and wages, general mining processes, and production; gives geologic sketch, discusses source of placer gold, and describes the several localities. L.

TIN AND TUNGSTEN.

Occurrence of Wolframite and Cassiterite in the Gold Placers of Deadwood Creek, Birch Creek District. By B. L. JOHNSON. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 246–250.

Sketches geography and geology and states the occurrence and value of the minerals. They may be of economic importance if saved as by-products and separated. L.

NON-METALLIC DEPOSITS.

ASBESTOS.

The Production of Asbestos in 1909. By J. S. DILLER. Advance chapter from Mineral Resources of the United States for 1909. U. S. Geol. Survey, 1910. L.

CLAYS.

Fuller's Earth and Brick Clays Near Clinton, Massachusetts. By W. C. ALDEN. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 402–404.

Describes exposure of glacial lake clay (the only glacial clay used for fuller's earth) and a few other exposures of glacial brick clay. L.

Vorkommen und Entstehung der Kaolinerde des Ostthüringischen Buntsandsteinbeckens. By F. WEISZ. Zeitschrift für praktische Geologie. Heft. 10, Oktober, 1910, p. 353. S.

COAL AND PEAT.

Alaska Coal and its Utilization. By A. H. BROOKS. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 47–100.

Gives geologic distribution, composition, areas of coal lands and coal fields, tonnage estimates, descriptions of the several coal fields, mining developments, geographic control of developments, cost of mining and marketing, value of Alaska coal lands, market, and bibliography. L.

Preliminary Report on the Peat Deposits of Florida. By R. M. HARPER. 3d Ann. Report, Florida State Geol. Survey. 1910, pp. 197–366.

Gives a general discussion, distribution, classification of Florida peat deposits, analyses, utilization, a catalogue of peat-forming plants and a bibliography (general and local) of eight pages. L.

The Preparation and Use of Peat as Fuel (with Special Reference to Alaska). By C. A. DAVIS. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 101–132.

Gives a general discussion of peat, including conditions favoring its formation, distribution of peat in Alaska, methods of estimating and working deposits, use for fuel in Alaska, and a selected bibliography. L.

GYPSUM.

The Gypsum Deposits of the Palen Mountains, Riverside County, California. By E. C. HARDER. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 407–416.

Gives general account of (future) commercial importance, geology and structure and origin of the gypsum beds. L.

Gypsum Deposits Near Cane Springs, Kern County, California. By F. L. HESS. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 417–418.

Gives description and analysis of gypsite in a playa deposit. L.

OIL AND GAS.

Natural Gas in North Dakota. By A. G. LEONARD. Bull. U. S. Geol. Survey. No. 431–A, 1910, pp. 3–6.

Describes locations, gives two analyses and two well records. L.

The San Juan Oil Field, San Juan County, Utah. By H. E. GREGORY. Bull. U. S. Geol. Survey. No. 431–A, 1910, pp. 4–21.

Gives brief accounts of location, climate, vegetation, supplies, fuel and labor, laws controlling claims, and topography; describes geology, including detailed sections of the oil sands; considers development, prospects and market. L.

Gas and Oil Prospects Near Vale, Oregon, and Fayette, Idaho. By C. W. WASHBURNE. Bull. U. S. Geol. Survey. No. 431–A, 1910, pp. 22–51.

Describes topography, stratigraphy and structural geology; discusses the several gas and oil occurrences, and proposes the tentative hypoth-

esis that the oil and gas are of solfataric origin; summarizes economic conditions. "The field bears no geologic resemblance to any other oil or gas field in the United States, with the possible exception of the prospective gas field at Salt Lake." L.

Gas Prospects in Harney Valley, Oregon. By C. W. WASHBURNE. Bull. U. S. Geol. Survey. No. 431–A, 1910, pp. 52–53.

Brief notes on a few prospects in strata similar to those in the Snake River valley. L.

Preliminary Report on the Geology and Oil Prospects of the Cantua-Panoche Region, California. By R. ANDERSON. Bull. U. S. Geol. Survey. No. 431–A, 1910, pp. 54–83.

Gives a general account of the geology (14 pp.) and discusses areas where oil may possibly occur. The region does not promise to be an extension of the Coalinga field, but in certain areas of it the conditions are fairly good. L.

Oil Resources of California. By M. L. REQUA. Address delivered before the Mining Association, Univ. of California, Berkeley.

Summarizes necessary geological conditions for accumulation of oil in commercial quantities, reviews estimates of the distribution and quantity of oil in California, and discusses uses, market, and cost of production. L.

Occurrence of Oil and Gas. By W. FORSTNER. Min. & Sci. Press. Vol. 101, No. 20, 1910, pp. 634–637.

The oil, gas, and other products occur within the McKittrick formation, in beds of shale and sandstone which lie directly conformable on top of the Middle Miocene shales in Kern County, California. The lower zone is the most productive, and it is suggested that the oils originated in the Middle Miocene diatomaceous shales. A.

Das lichte Erdöl von Ssurachany bei Baku als Filtrationsprodukt. By H. HOFER. Petroleum, 1910, No. 11. (Short abstract in Geol. Zentralblatt, Bd. 15, No. 7, 1910.)

Gives evidence showing that the filtration hypothesis will not account for the light oil. L.

PHOSPHATES.

A Preliminary Paper on the Florida Phosphate Deposits. By E. H. SELLARDS. 3d Ann. Report, Florida State Geol. Survey. 1910, pp. 21–41.

Gives lithologic descriptions, stratigraphic relations, source of materials, conditions of deposition, and local descriptions. The hard rock phosphate formation is of residual character more or less modified by local transportation and deposition; the pebble phosphate

material was deposited in shallow water by conflicting currents. Statistics for 1909 are given. L.

SALT.

Niewe opvattingen over de geologie der Zechsteinzouten en de beteekenis daarvan voor het voorkomen van zoutlagen in Nederland. By H. G. JONKER. Chemisch Weekbad (Amsterdam, D. B. Centen. 8°). Jahr. VII., 1910, No. 34, pp. 741–755. (Short abstract by author in Geol. Zentralb., Bd. 15, No. 8, 1910, p. 377.)

An account of the geology with profiles of borings. Salt in part occurs as thick well-defined pure beds; in part as irregular impregnations. L.

STRUCTURAL MATERIALS.

Gravel and Sand in the Pittsburg District, Pennsylvania. By E. W. SHAW. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 388–399.

Outlines geology, and describes methods of working and preparation, and states uses, production and value. L.

Cement Materials in Republican Valley, Nebraska. By N. H. DARTON. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 381–387.

Gives brief account of geology, and describes limestone and shale. L.

Structural Materials available in the Vicinity of Minneapolis, Minnesota. By E. F. BURCHARD. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 280–291.

Describes available supplies of granite, sandstone, magnesian limestone, rubble and range rock, materials for concrete, clay products, and materials for lime and plaster. L.

Structural Materials available in the Vicinity of Austin, Texas. By E. F. BURCHARD. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 292–316.

Describes available supplies of limestone, granite, materials for concrete, brick, mortar and plaster, and Portland cement. L.

The Slates of Arkansas. By A. H. PURDUE. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 317–334.

Outlines history of the slate industry of Arkansas, and the origin of slate. Describes the geology of the slate area, and the characters of the slates. Gives tests of the slate. L.

The Oölitic Limestone Industry at Bedford and Bloomington, Indiana. By J. A. UDDEN. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 335–345.

Describes the geology and discusses economic data as follows: quarries, mills, waste and its utilization, Portland cement materials, labor conditions and wages, shipping facilities and rates, commercial value. L.

Oölitic Limestone at Bowling Green and Other Places in Kentucky. By J. H. GARDNER. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 373–378.

Describes occurrence, distribution, and character of the Bowling Green stone; available stone near Somerset and elsewhere. L.

Supplementary Notes on the Granites of New Hampshire. By T. N. DALE. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 346–371.

Chiefly descriptions of quarries, followed by a commercially classified table including all the granites in the State of known commercial value. L.

TALC AND SOAPSTONE.

The Production of Talc and Soapstone in 1909. By J. S. DILLER. Advance chapter from Mineral Resources of the United States for 1909. U. S. Geol. Survey, 1910. L.

WATER.

Geology and Water Resources of the San Luis Valley, Colorado. By C. E. SIEBENTHAL. Water-Supply Paper, U. S. Geol. Survey. No. 240, 1910, pp. 128, with XIII. plates and 15 figures.

47 pages devoted to geography and to geology, 50 pages to general considerations of underground waters, 6 pages to characteristics of the San Luis artesian basin, 6 pages to quality and uses of the water, and 7 pages to costs of boring wells and to measurements of artesian flow. L.

Water Powers of the Cascade Range, Part I., Southern Washington. By J. C. STEVENS. Water-Supply Paper, U. S. Geol. Survey. No. 253, 1910, pp. 94, with 21 plates and 3 figures.

States conditions governing hydraulic development, water laws, and conditions affecting stream flow; gives descriptions and measurements for the several drainage basins. L.

Preliminary Report on the Ground Waters of Estancia Valley, New Mexico. By O. E. MEINZER. Water-Supply Paper U. S. Geol. Survey. No. 260, 1910, pp. 33.

Outlines geology; discusses source and disposal of water, ground-water table, recovery of ground water, quality of water, irrigation, costs and uses. Irrigation projects should succeed if conducted with proper care. L.

Surface Water Supply of the United States, 1909, Part II.; South Atlantic Coast and Eastern Gulf of Mexico. Prepared by M. R. HALL and R. H. BOLSTER. 1910, 150 pp., 5 plates.

Part IV.; St. Lawrence River Basin. Prepared by C. C. COVERT, A. H. HORTON, and R. H. BOLSTER. 1910, 130 pp., 5 plates. L.

The Artesian Water Supply of Eastern Florida. By E. H. SELLARDS and H. GUNTER. 3d Ann. Report, Florida State Geol. Survey. 1910, pp. 77–195.

Describes geology, topography and drainage, climate and soils; gives general discussions of underground and artesian water, and detailed discussion by counties. L.

The Underground Waters of North-Central Indiana. By S. R. CAPPS, with a chapter on the chemical character of the waters, by R. B. DOLE. Water-Supply Paper, U. S. Geol. Survey. No. 254, 1910. Pp. 279, with 7 plates and 12 figures.

The main part of the paper deals with geography, geology, the sources, movements, and occurrence of ground water, public supplies, and detailed descriptions; the chapter on chemical characters includes classification for different uses, purification, and chemical composition. L.

Underground Waters for Farm Use. By M. L. FULLER. Water-Supply Paper, U. S. Geol. Survey. No. 255, 1910. Pp. 58, with 17 plates and 27 figures.

Discusses sources of water supply, underground waters and their protection, cisterns, and the combination of wells and cisterns. L.

A Water-Power Reconnaissance in Southeastern Alaska. By J. C. HOYT. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 147–157.

Gives brief account of topography, geology, climate (with tables of temperature and precipitation) and vegetation. Discusses (with diagrams) general conditions of run-off, industrial conditions and power possibilities. L.

Water Supply of the Yukon-Tanana Region, 1909. By C. E. ELLSWORTH. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 251–283.

States conditions affecting supply, precipitation, hydraulic development, explanations of data and methods, describes the several districts with reference to water supply. L.

Water-Supply Investigations in Seward Peninsula in 1909. By F. F. HENSHAW. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 372–418.

Chiefly tables showing discharge of rivers, creeks and ditches. L.

REGIONAL REPORTS.

A Reconnaissance of Parts of Northwestern New Mexico and Northern Arizona. By N. H. DARTON. U. S. Geol. Survey. Bull. 435, 1910. Pp. 88, 17 plates and 8 figures.

Gives results of geologic investigation in the vicinity of the A. T. & S. F. Rr., from Albuquerque, N. Mex., to Kingman, Ariz., to deter-

mine prospects for obtaining deep-seated underground water supplies. Deals chiefly with stratigraphy and structure. Pp. 75–81 contain boring records and state the amount of water obtained in each case. L.

Present Mining Conditions in Nicaragua. By T. L. CARTER. Mining Science. Jan. 5, 1911.

A brief description of the geology and vein system is given. S.

Der Bastenberger Gangzug bei Ramsbeck in Westfalen und sein Nebengestein. By A. EICKHOFF. Zeitschrift für praktische Geologie. Heft 8, Aug., 1910. S.

The Geology of New Zealand. By J. PARK. Pp. 488 with 27 plates, 145 figures, and a colored geological map. London; Whitcombe and Tombs, Limited, 1910. (Reviewed in Jour. Geology, XIX., 1911, p. 91.)

Gives general geology, a section on economic geology, especially coal and gold, and a complete bibliography. L.

Florida State Geological Survey, Third Annual Report, 1909–1910. By E. H. SELLARDS, State Geologist. Tallahassee, Fla., 1910. Pp. 395, with 28 plates and 30 text figures.

Contents: Administrative report; a preliminary paper on the Florida phosphate deposits, by E. H. Sellards; some Florida lakes and lake basins, by E. H. Sellards; the artesian water supply of eastern Florida, by E. H. Sellards and H. Gunter; a preliminary report on the Florida peat deposits, by R. M. Harper. L.

Mineral Resources of Alaska. Report on Progress of investigations in 1909. By A. H. BROOKS and others. Bull. U. S. Geol. Survey. No. 442, pp. 432, with 8 plates and 8 figures.

Contains administrative report and an account of the mining industry for 1909, by A. H. Brooks, and several papers listed elsewhere in this bibliography. L.

Mining in Southeastern Alaska. By A. KNOPF. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 133–143.

Describes mines and prospects, of gold (and silver) and of copper. L.

Outline of the Geology and Mineral Resources of the Iliamna and Clark Lakes Region. By G. C. MARTIN and F. J. KATZ. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 179–200.

Describes geography, geology, mineral resources and mining development. L.

Preliminary Report on the Mineral Resources of the Southeastern part of Kenai Peninsula. By U. S. GRANT and D. F. HIGGINS. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 166–178.

Gives geology, mineral prospects of iron, copper, gold, silver, antimony and coal. L.

Mining and Prospecting on Prince William Sound in 1909. By U. S. GRANT. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 164–165.

A brief progress report. L.

Mining in the Chitina District (Alaska). By F. H. MOFFIT. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 158–163.

Describes conditions in 1909; the Bonanza mine and other copper claims and prospects; also progress in placer gold mining, and in geologic investigations. L.

Mineral Resources of the Nulato-Council Region. By P. S. SMITH and H. M. EAKIN. Bull. U. S. Geol. Survey. No. 442, 1910, pp. 316–352.

Gives geography and general geology, economic geology (gold lodes and placers, silver-lead deposit, and coal resources). L.

ORE DEPOSITS.

Alterverschiedenheiten bei Mineralien der Kieslager. By R. CANAVAL. Zeitschrift für praktische Geologie. Heft 5 & 6, Mai–Juni, 1910. S.

Uber primäre und sekundäre metasomatische Prozesse auf Erzlagerstätten. By P. KRUSCH. Zeitschrift für praktische Geologie. Heft 5 & 6, Mai–Juni, 1910. S.

Crushing of Rocks in Connection with Ore Deposits. By A. LAKES. Mining Science, Dec. 22, 1910. S.

UNCLASSIFIED.

Contributions to Economic Geology, 1909. Part I.—Metals and non-metals except fuels. C. W. HAYES and W. LINDGREN, geologists in charge. Bull. U. S. Geol. Survey. No. 430, 1910, pp. 653, with 14 plates and 75 figures.

Contains many papers listed in the present or previous bibliographies. L.

Bibliography of North American Geology for 1909, with Subject Index. By J. M. NICKLES. Bull. U. S. Geol. Survey. No. 444, 1910, pp. 174. L.

SCIENTIFIC NOTES AND NEWS[1]

PROFESSOR C. K. LEITH, of the University of Wisconsin, gave a lecture before the advanced students in geology at Northwestern University on January 26. His subject was a comparison of the origins of the iron ores of the Lake Superior region, of Cuba, and of Brazil.

FREDERICK G. CLAPP has enlarged his "Geological Engineering Practice," and will now specialize in examining and reporting on coal in addition to oil, gas and water propositions as heretofore.

C. V. GOULD, mining engineer, graduate of the Armstrong College of Science, Durham University, England, and for fourteen years coal expert in England and America, will be in charge of this branch of the work. The general offices will be maintained at 331 Fourth Ave., Pittsburgh, Pa.

AT the 238th meeting of the Geological Society of Washington, on January 25, 1911, Mr. Waldemar Lindgren read a paper on "The Iron Ores of Sweden."

AT the 239th meeting of the Geological Society of Washington, on February 8, 1911, the following papers were read: C. W. Hayes, "Some Exceptional Conditions of Petroleum Accumulation"; F. L. Hess, "The Scheelite Deposits at Atolia, California"; E. S. Bastin, "Some Features of Graphite Deposits of the United States."

RECENT appointments in the School of Mines of the University of Pittsburg are Dr. Charles R. Eastman, of Harvard

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

University, as professor of paleontology; Otto Emery Jennings, B.S., of the Carnegie Museum, as instructor in paleobotany, and James Z. Zimmerman, as assistant in mining.

MR. GEORGE T. HALDEMAN, E.M., instructor in mining at Lehigh University, has recently been appointed superintendent of the Mine Rescue Work of the Lehigh Valley Coal Company and Mr. Edward L. Estabrook, assistant in mineralogy, has been appointed instructor in petrology at Lehigh University.

J. B. TYRRELL, mining engineer, of Toronto, has opened a branch office in Porcupine, in northern Ontario.

F. KRANTZ, of Bonn, Germany, has arranged to prepare scales of refringence illustrating the degrees of refringence occurring in minerals, and useful in connection with tables for the determination of minerals microscopically, such as those published in Winchell's "Optical Mineralogy."

ERNST LEITZ has received from the University of Marburg, the degree of doctor of philosophy on account of his meritorious services rendered to science, by having constructed for over fifty years instruments of the greatest scientific value.

ILLINOIS resumed her continuous growth in oil production in 1910, after the relapse of 1909. The estimated production for the year is 35,000,000 bbls., as against 30,898,339 in 1909, and 33,685,106 in 1908. The increase was due indirectly to general market conditions and the ability of various pipe lines to cope with the supply. The introduction of new pipe lines into the field late in 1909 materially aided in the increased activity. The basis of estimating the production, since only eleven months' returns are available, is to assume the December runs of the Ohio Oil Company equivalent to those of November; the tank-car shipments to be about 2,000,000 bbls., and miscellaneous pipe-line runs to be 4,680,000 bbls. The latter runs are based upon a daily average of 12,000 bbls., for the first six months, 16,000 bbls., for the next three months, and 12,000 bbls., for the last three months of the year.

PROFESSOR J. D. IRVING on February 7 and 8 gave two lectures on "Replacement" at McGill University, Montreal.

THE following resolution has been before the council of the Mining and Metallurgical Society of America, and has been approved by a majority of that body: "*Resolved* that the Mining and Metallurgical Society of America award annually, under rules to be subsequently formulated by the council, a gold medal valued at $100 to the person who, in the opinion of the society, has done most during the previous year to advance the arts of mining and metallurgical engineering, said medal to be awarded without regard to membership in the society."

The following resolution, signed by twenty-three members, was presented at the annual meeting, and subsequently received the approval of the council: "*Resolved* that in the opinion of the Mining and Metallurgical Society of America, state in pectors of mines should be appointed, and should not be elected."

IN THE PAPER by Dr. Per Geijer in Vol. V, No. 8, of this journal, certain corrections by the author were not received in time for incorporation in the proof. We take pleasure in listing them below:

Fig. 64, p. 701, the latter part of the legend should read: "6, quartzites, etc.; 7, phyllite and graywacke; 8, sandstone." The letters E and W on the section should be transposed.

The author desires us to state that, as originally submitted this article was intended as a review of his monograph on the Kiirunavaara iron ores.[1] Owing to its length and importance it was inserted as a special article.

[1] "Igneous Rocks and Iron Ores of Kiirunavaara, Luossavaara and Tuollovaara, Scientific and Practical Researches in Lapland, arranged by Luossavaara-Kiirunavaara Aktiebolag. Stockholm, 1910."